It’s all in the mix

Agroforestry, a prospective land use system for the Netherlands

Michel Postma

Group Plant Production Systems
Department of Plant Sciences
Wageningen University
It’s all in the mix

Agroforestry, a prospective land use system for the Netherlands

Michel Postma

MSc Thesis Plant Production Systems

January 2005

Supervisors
Martina Mayus (Crop and Weed Ecology Group)
Anne Oosterbaan (Alterra)

Examiners
K.E. Giller (Group Plant Production Systems)
H. van Keulen (Group Plant Production Systems)

Group Plant Production Systems
Department of Plant Sciences
Wageningen University

Haarweg 333
P.O. Box 430
6700 AK Wageningen
The Netherlands
Preface and acknowledgements

During my study Tropical Land Use, through various courses and an internship in Nicaragua, I got interested in agroforestry. I learned and personally observed the benefits of mixing trees and crops in tropical agro-ecosystems. It made me wonder, if agroforestry could also be valuable in Europe…it made me wonder also, observing the farming landscape in The Netherlands, why I only saw monotonous monocultures. I decided to find out though my thesis research, at the back of my head a dream to once establish an agroforest on my own farm.

With this report I want to shed a light on what the value of agroforestry could be in the Netherlands. I also hope to clarify what currently constrains the establishment of agroforestry. Hopefully this will make more people aware of the possibility of agroforestry as a sustainable multiple land use system and give handles for its successful application in The Netherlands.

This report would not have been what it is without the support of many people. First of all, I would like to thank Herman van Keulen, who put me on the right track, when I was looking for people in this field of research. He pointed me at Martina Mayus and at Anne Oosterbaan. I want to express my gratitude to both Martina and Anne for their important contribution to this thesis research. Without their experience and constructive comments for improvement and change, this thesis would not have been possible.

I would like to convey my appreciation to all the farmers and estate owners, who I visited during the survey, which formed an important part of this research. Thank you for your hospitality and your willingness to cooperate and share your views and ideas. You were a great deal of my motivation!

The survey was carried out as part of the EU funded research project SAFE (Silvoarable Agroforestry For Europe). The financial support, which has given me the opportunity to carry out this survey and present the results at a SAFE workshop in Toulouse, is gratefully acknowledged.

Last but not least, I would like to say thanks to my family and friends, who have greatly helped and encouraged me during this thesis.

“A farm can be regarded as a food factory and the criterion for its success is saleable products. Or, it can be regarded as a place to live, and the criterion for its success is harmonious balance between plants, animals and people; between the domestic and the wild; and between utility and beauty.”

Aldo Leopold

3
SUMMARY

The decreasing incomes of farmers, the overproduction of agricultural commodities and the increasing pressure on agricultural land to address more functions than arable production demands us to take a wider view and to search for alternative crops and sustainable multiple land use system in the Netherlands. Agroforestry, the production of trees and crops and/or livestock on the same plot, may be an answer. Research indicates that agroforestry systems are very efficient in terms of resource use and could introduce an innovative (agricultural) production system that will be both environmentally friendly and economically profitable. Agroforestry offers opportunities to achieve national policy goals of increasing tree planting and extensification of agriculture, improving farm biodiversity.

This study explores the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands. To get insight in the potential of modern agroforestry in the Netherlands, where currently agroforestry plays almost no role, a holistic approach was aimed for, assessing the ecological, technical and socio-economic aspects of agroforestry.

Through literature research the main agroforestry practices that would be appropriate and innovative were identified, the advantages and disadvantages of agroforestry related to the situation in The Netherlands were reviewed and a selection was made of tree and intercrop species that have proven their value in temperate agroforestry and/or are expected to be promising under Dutch conditions.

Based on website-information of the ministry of LNV (Agriculture, Nature Conservation and Fisheries) an overview was made of the restrictions of the Dutch forest law and of governmental subsidies, which may be eligible for agroforestry.

Land users’ perspectives on agroforestry will determine the eventual adoption of agroforestry. Their point of view have to be considered for the design of viable agroforestry systems. Therefore and as part of the Silvoarable Agroforestry For Europe (SAFE) project, a survey was carried out to investigate the attitude of Dutch land users towards agroforestry and to assess the conditions of acceptability of new agroforestry systems. In January 2004, the interviews were held with 27 farmers and 2 estate owners in two rather different regions in the Netherlands, namely the Achterhoek and North-Friesland.

Finally all information was synthesized and the constraints and opportunities for the establishment of new agroforestry systems in The Netherlands were discussed. Some examples of possible agroforestry designs are given for farmers, foresters and hobby/small-scale farmers.

Four distinct agroforestry practices are considered to be appropriate and innovative for The Netherlands, namely:
- silvoarable agroforestry, comprising widely-spaced trees and/or shrubs associated with arable crops
- silvopastoral agroforestry, a combination of trees, forage (pasture) and livestock production
- forest gardening, comprising multi-species and multi-storied dense plant associations, planted and/or managed in such way that they mimic the structure and the ecological processes of natural forests
- forest farming, the cultivation of edible, medicinal or decorative specialty crops as under-storey in (semi)natural woodlands
There is a variety of tree species that would fit in such practices in The Netherlands and provide wood and/or secondary products. Potential tree species are considered:

- **multipurpose trees** that have proven their value and their suitability to the Dutch environment, e.g. walnut (\textit{Juglans} spp.), chestnut (\textit{Castanea sativa}), hazelnut (\textit{Corylus} spp.), sweet cherry (\textit{Prunus avium}) and other fruit trees
- **trees** with fast (juvenile) growth, which may be suitable for short- and mid-term rotations (< 50 years), e.g. poplar (\textit{Populus} spp.), willow (\textit{Salix} spp.), alder (\textit{Alnus} spp.), ash (\textit{Fraxinus excelsior}) and maple (\textit{Acer} spp.)
- **multipurpose species** that are not yet cultivated on a commercial scale in the Netherlands, but that have a potential for Dutch agroforestry mainly due to their secondary products, e.g. honeylocust (\textit{Gleditsia triacanthos}), hawthorns (\textit{Crataegus} spp.), elaeagnus spp., buckthorn (\textit{Hippophae} spp.), strawberry tree (\textit{Arbutus unedo}), mulberry (\textit{Morus} spp.) and other ‘specialty trees’.

Most species of the last group are new for The Netherlands and/or have not yet been tested in agroforestry environments. Further research is required to assess their potential.

Growing trees in association with arable crops and/or livestock may improve the sustainability of farming systems, diversify farmers’ incomes, provide new products, and create attractive landscapes for both wildlife and people. Major disadvantages are the high investment costs, the necessity of new skills and possibly higher labour demands. Well designed silvoarable and silvopastoral system offer farmers the opportunity to apply common machinery and continue with the usual crop rotation on the agroforestry field for several years, providing sustainability of farm income in the early stage.

In The Netherlands, on the long term, the cultivation of common light-demanding crops in agroforestry systems may not be beneficial, because sub-optimal light conditions may seriously reduce crop yields or may cause problems with grain ripening. At this point, replacement of the light demanding crop by shade-tolerant forages and pastures may be considered. Livestock may benefit from the shelter provided by trees, but (young) trees need to be well protected to prevent damage.

There is a broad range of interesting alternatives, which can produce valuable products in the (partially) shaded alleys, both on a large scale for the bulk market and on a smaller scale for certain niche markets. Many of these are new for the Netherlands and require further research to assess their potential for agroforestry applications. Examples are:

- **small-fruit species** as \textit{Vaccinium} spp., \textit{Ribes} spp., \textit{Rubus} spp., \textit{Actidinia} spp. and various other berry species
- **specialty crops** as ornamental species, medicinals, specialty vegetables and gourmet mushrooms
- **non-food crops** for fiber and biomass production, as hemp and willow short rotation coppice

Small fruit species and specialty crops are particularly suitable for cultivation in forest farming and forest gardening systems. Crops for fibre and biomass production seem to have good prospects and show high potential for agroforestry applications, in particular on intensive farms. Instead of leaving tree strips in silvoarable and silvopastoral systems bare or fallow, they could also be grown with a shade tolerant or specialty crop on the tree strip, e.g. Christmas trees, fruit shrubs, flower bulbs, decorative florals, mushrooms and flowers for honey production.

Notwithstanding the promising opportunities of agroforestry, there are some formidable constraints that prevent the realization of the potential benefits. A major constraint is institutional. Agroforestry is not recognized as an official land use class. This discourages AF, as (in most cases) agroforesters can neither receive the grants for forestry plantations, nor those for agricultural crops. National laws oblige farmers to harvest trees before age 40 to prevent agroforestry plots shifting to a forest status and considerably decrease in value.
Local regulations may impede the planting or felling of trees or force farmers to replant trees after felling.

Until now, there has been little attention (and funding) for agroforestry in Europe and the Netherlands. The lack of an adequate research base, practical demonstrations and extension agents and advisers who are able to address agroforestry issues hampers the development of agroforestry, as farmers and other land users often lack the knowledge and skills.

At present only large farms may be able to bear the investment costs for tree establishment, unless subsidies are provided for the smaller ones. Apart from the fact that most land users in the Netherlands are not aware of the possibility of agroforestry as an alternative land use system, few will be inclined to adopt it as long as the financial benefits are not proven and demonstrated. Applied research, practical demonstrations and institutional support are recommended to develop agroforestry on a large scale and to realize the benefits it offers.

Although the concept is new for them, farmers in the Netherlands have indicated to be interested in agroforestry as an alternative land use system, if it is shown to be economically viable in the Netherlands. In the Achterhoek farmers are more open to agroforestry than in Northern Friesland, possibly because decreasing farm profits in the sandy areas and the limits to further intensification force farmers in this region to take a broader view on agriculture. Furthermore, they already have experience with trees and are more open to cooperation with neighbours and landlords.

Farmers in both regions see a lot of negative aspects of agroforestry, mostly technical such as mechanization, labor, and lower revenues on the intercrop. Most farmers emphasize the need for subsidies to compensate for the losses on the revenues of the intercrop and the expected extra costs for labour and tree maintenance. Another constraining factor is the lack of knowledge on tree management, tree returns and the market for tree products. Since most farmers have the experience to gain little or no money by the sale of tree products, they have little confidence in the profitability of agroforestry.

Since farmers have little or no experience with growing trees and agroforestry in particular, they find it hard to decide how they would design an agroforestry system. Farmers pointed out to need much more background information and practical examples to make reasonable decisions.

62% of the respondents in the Achterhoek said they would like to try an agroforestry project. Only 27% of the Friesian farmers were enthusiastic to try an agroforestry project. Whether respondents would adopt agroforestry would not so much depend on respondents’ age, but rather on profitability, the subsidies and on the (availability of a) successor.

To develop agroforestry in the Netherlands, first the forementioned structural constraints should be alleviated. Policies should recognize agroforestry as a legal land use status and adapt grant regulations and laws accordingly. Research and extension should get more acquainted with agroforestry, prove its benefits in the Netherlands and share this knowledge with farmers. Eventually agroforestry systems should be designed, which take into account the technical, ecological and socio-economic constraints and opportunities and the objectives of different land users. In Chapter 8 some scenarios are given for three potential groups of agroforesters in the Netherlands, i.e. commercial farmers, foresters and small-scale/hobby farmers.
# Table of Contents

PREFACE AND ACKNOWLEDGEMENTS.................................................................................................................. 1

SUMMARY.............................................................................................................................................................. 109

1. INTRODUCTION .............................................................................................................................................. 115
   1.1 GENERAL BACKGROUND.......................................................................................................................... 115
   1.2 AGROFORESTRY AS SUSTAINABLE AND MULTIPLE LAND USE SYSTEM ............................................ 115
   1.3 UNDERSTANDING AND CHANGING LAND USE PRACTICES .................................................................... 117
   1.4 CONCEPTS AND DEFINITIONS................................................................................................................ 118
   1.5 RESEARCH AIM AND QUESTIONS.............................................................................................................. 119
   1.6 METHODOLOGY AND OVERVIEW OF THIS THESIS.............................................................................. 120

2. POTENTIAL AGROFORESTRY SYSTEMS: CHARACTERIZATION AND MAIN PRACTICES.......................... 122
   2.1 INTRODUCTION ......................................................................................................................................... 122
   2.2 CLASSIFICATION OF AGROFORESTRY SYSTEMS AND PRACTICES ......................................................... 122
   2.3 CHARACTERIZATION OF INNOVATIVE AGROFORESTRY SYSTEMS FOR THE NETHERLANDS .............. 122
   2.4 POTENTIAL AGROFORESTRY PRACTICES FOR THE NETHERLANDS ................................................... 123
      2.4.1 Silvoarable practices .......................................................................................................................... 124
      2.4.2 Silvopastoral practices...................................................................................................................... 125
      2.4.3 Forest gardening .............................................................................................................................. 126
      2.4.4 Forest farming .................................................................................................................................. 127

3. ADVANTAGES AND DISADVANTAGES OF AGROFORESTRY...................................................................... 128
   3.1 INTRODUCTION ......................................................................................................................................... 128
   3.2 ADVANTAGES OF AGROFORESTRY........................................................................................................ 128
      3.2.1 Ecological and environmental advantages ....................................................................................... 128
      3.2.2 Socio-economic advantages............................................................................................................ 131
   3.3 DISADVANTAGES OF AGROFORESTRY ................................................................................................... 133
      3.3.1 Negative ecological interactions ...................................................................................................... 133
      3.3.2 Socio-economic disadvantages........................................................................................................ 135

4. TREES FOR TEMPERATE AGROFORESTRY SYSTEMS, IN PARTICULAR THE NETHERLANDS .................. 139
   4.1 INTRODUCTION ......................................................................................................................................... 139
   4.2 FAST GROWING TREES ............................................................................................................................ 139
      4.2.1 Short rotation trees ............................................................................................................................ 139
      4.2.2 Mid-term rotation species ................................................................................................................ 141
   4.3 MULTIPURPOSE TREES........................................................................................................................... 141
      4.3.1 Upper storey trees ............................................................................................................................ 141
8. SYNTHESIS AND DISCUSSION: ROADMAP FOR ADOPTION AND DESIGN OF NEW AGROFORESTRY SYSTEMS

8.1 INTRODUCTION

8.2 LIMITING FACTORS AND SOLUTIONS FOR THE ADOPTION OF AF

8.2.1 Lack of basic knowledge and skills

8.2.2 Structural constraints

8.2.2.1 Research and extension

8.2.2.2 Governmental policies

8.2.3 Other socio-economic factors

8.2.3 Practical limitations

8.3 OPPORTUNITIES FOR THE WIDER ADOPTION OF AF: MATCHING DESIGN AND AGROFORESTER

8.3.1 Farmers

8.3.2 Foresters

8.3.3 Hobby/small-scale farmers

8.4 CONCLUSIONS

REFERENCES

APPENDIX: MAJOR APPROACHES TO CLASSIFICATION OF AGROFORESTRY SYSTEMS AND PRACTICES

ATTACHED REPORT: SURVEY OF FARMERS' REACTION TO NEW TO NEW SILVOARABLE AND SILVOPASTORAL SYSTEMS IN THE NETHERLANDS
1. INTRODUCTION

1.1 General background

In the Netherlands there is an ongoing debate about the role and future function of rural areas. Many farmers are worried about their future. Decreasing incomes and more regulations cause daily 8-10 farmers to stop their business (Aarde, boer, consument 2002). At the same time, there is an increasing pressure on agricultural land to address more functions than production, for instance bird-protection and other wildlife support, environmental protection, maintenance of cultural elements and recreation. To keep agriculture viable in the Netherlands, where land is scarce and societal demands are high, we need to look at land use systems, which can combine several of such functions.

In traditional agriculture, crops were selected to match the site, which generally experienced only the amendment that one farmer could achieve with his own hands (Ashton 2000). Risks were spread by the use of a variety of crops and the heterogeneity in genotypes was large. Fallows, crop rotations and mixing of crops, trees and/or animals were used to maintain and improve production. Furthermore hedges and trees were often included in the farmland to provide field boundaries and services as timber, fencing, firewood, edible products, fodder, shade, nutrients and wind-protection. This resulted in a diverse and small scale rural landscape.

Since the 50s, through the introduction of agrochemicals and enormous advances in crop genetics and agrotechnology, combined with policy measures favoring intensification, agriculture has changed enormously. Farming has been highly intensified and specialized and food production has risen considerably. The arable land has undergone amendment and homogenization of site conditions to fit the specific cropping demands of a farm, often comprising only one or a few species and genotypes. Although rotations of several species remain an important part of modern farming, intercropping is being practiced at a very limited scale.

Nowadays we realize the negative side effects of this type of farming, for instance groundwater pollution, eutrophication of water bodies, low biodiversity and overproduction and measures are being taken to promote a more extensive and diversified land use.

Moreover, developments after the second world war targeted at separation of functions like agriculture, nature conservation and recreation. At present, increasing demands for land in the Netherlands has resulted in an increasing pressure on agricultural land and the need for efficient use of this resource. Therefore the concept of multiple land use has received increasing attention in the last decades. Multiple land use is defined as “land use aiming at the generation of more than one type of product and/or services” (Londo 2002).

This altogether has led to a search for new and more sustainable land use systems, which can offer multiple products and/or functions. Within that context, this report explores the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands.

1.2 Agroforestry as sustainable and multiple land use system

The intensive production of agricultural and forestry monocultures is unique to advanced developed countries, while worldwide the separation of agriculture and forestry has proven to be difficult. Up to present, agroforestry has remained the primary land use approach in many parts of the developing world. Complex indigenous farming systems, producing a multitude of
products such as timber, firewood, food, fiber, forage and medicines have operated effectively for centuries (Nair 1993). In addition to a multitude of products for direct use and/or sale, such complex systems offer a level of environmental protection (i.e. conservation of the natural resources) unmatched by modern land use technologies (Young 1989, Nair 1993). The link of production and protection forms the basis for the concept of sustainability, which is central to international development activities aiming to break the negative feedback relationship between intensive land use and progressive environmental degradation (Lassoie and Buck 2000).

Indigenous and modern agroforestry systems in the tropics have received ample attention during the last decades. Recently, the application of agroforestry in developed countries has been receiving more and more attention. Since the needs for enhanced environmental protection through sustainable land use will only continue to grow, it is expected that the interest in agroforestry will continue to grow, also in the Western world.

However less complex, recent findings indicate that also modern silvoarable production systems are very efficient in terms of resource use, and could introduce an innovative agricultural production system that will be both environment-friendly and economically profitable (SAFE 2004). Within this context, recently the Europe-wide SAFE1 project was set up, in order to further assess the validity of silvoarable systems and to suggest unified European policy guidelines for implementing agroforestry (SAFE 2004). Also current research on modern silvopastoral systems in the Netherlands within the framework of research on “multiple sustainable land use” within Wageningen UR, expressed the positive values and potentials of agroforestry (Oosterbaan et al. 2004). Furthermore the “Stichting Boslandbouw” has initiated several small-scale agroforestry plantings in the North of the Netherlands, which have proven to be profitable (Alterra 2003).

In many regions of the world, including most parts of the Netherlands, forests are ecologically the most optimum vegetation. Natural succession in these areas would eventually result in a forest stand. Contrary to common Dutch agricultural practices, the author of this report promotes the idea of working with natural processes rather than continuously attempting to control or fight against them. From this ecological perspective, it seems logical to implement well designed agroforestry systems as the agricultural production system in originally forested areas, since these come closest to the natural situation. Both ecological theory and empirical research suggest that mixed-species systems are indeed ecologically more stable (i.e. less susceptible to epidemic pests and diseases) and sustainable (i.e. more efficient in the use of above- and below ground resources) than monocropping systems (e.g. SAFE 2004, Ashton 2000).

Although modern agroforestry has proven its value in temperate America, and seems promising in temperate Europe as well, only few investigations have been undertaken on this subject in the Netherlands. It is only recently that modern agroforestry receives attention in The Netherlands and that researchers and other stakeholders with interest and knowledge of agroforestry are interchanging their experiences and views (Alterra 2003).

No findings are reported on the socio-economic viability of agroforestry as a new farming system, i.e. little is known about the insights and attitudes of farmers and other land-owners, regarding agroforestry. In view of the increasing attention for sustainable farming and multiple land use, it is now the time to seriously regard the possibility of agroforestry as a future land use type in the Netherlands.

1 Silvoarable Agroforestry For Europe (http://www.montpellier.inra.fr/safe)
Traditional agroforestry systems in the Netherlands have largely disappeared, with the exception of some small traditional orchards and poplar pastures, while modern systems have not yet been developed. However, windbreaks and riparian buffers are widely applied there where the land is prone to erosion and the fields are bordered by open water, respectively.

To get insight in the potential of modern agroforestry in the Netherlands, where currently agroforestry plays almost no role, this report aims at a holistic approach. It will regard the potential of agroforestry from a rational technical, ecological and economic point of view, but will also consider land users’ perspectives on agroforestry, as these will determine the eventual adoption of agroforestry and are necessary in the design of viable agroforestry systems. To be able to understand and influence the potential of adoption of modern agroforestry systems however, it is necessary to have a basic understanding of the variables that play a role in shaping human practices vis-à-vis their natural and social environment.

1.3 Understanding and changing land use practices

When considering land use practices (e.g. farming, forestry, agroforestry), one can distinguish between different domains of land use (Leeuwis and van den Ban 2004). Such domains are essentially different aspects that need to be considered while managing a land use system, namely technical, economic and social aspects. Important (sub)domains of land use practice that farmers and other land users are likely to take into account include (Leeuwis and Van den Ban 2004):

- **in the technical domain**: soil fertility, crop-protection, production and yield, storage facilities, spatial organization of the farm
- **in the economic domain**: income, profitability, marketability, taxes, investments, cash flow, credit, fixed costs, variable costs
- **in the domain of socio-organizational relations**, relations with: input providing organizations, organizations on the output-side, household and community members, farm laborers, religion

According to Leeuwis’ definition, the technical domain also includes ecological aspects of the land use system. Furthermore, land users have to coordinate their practices across different moments in time, i.e. they can do things with different time horizons in mind.

Similarly, Leeuwis argues that “the locus of agricultural decision-making is not so much the individual ‘head of the household’, but extends to household/community members and is also influenced by other actors in (or even) outside the agricultural production chain”.

This implies that the decision whether and how a land user will implement a certain innovation, in this case agroforestry, will thus not only be based on rational technical and economic considerations. Also other, often less tangible issues, such as identity, culture, conflict, religion, risk, trust can play a role in shaping land users’ practices. Leeuwis (Leeuwis and van den Ban 2004, adapted) summarizes it as follows: “land use practices are shaped in a series of social interactions between different people at various points in time and in different locations, within the context of a wider social system”.

In all, people’s practices, i.e. what they do or not do (and how they respond to proposed alternatives), depend on what they *aspire* (i.e. what they *want*), *believe* to be true about the biophysical and social world (i.e. what they *know*), and (think they) are *able* and *allowed* to do (Leeuwis and van den Ban 2004).
This report will shed a light on the various technical/ecological, economic and social factors related to agroforestry and thus playing a role in shaping land users’ perceptions of agroforestry, which eventually will affect the potential of agroforestry in The Netherlands.

1.4 Concepts and definitions

Agroforestry

Agroforestry is characterised by a high diversity and variable scope of practices, therefore many definitions of this system exist. Lundgren (1982) gave a broadly applicable definition, which is also the definition used by the “The World Agroforestry Centre” (the former ICRAF) (2004):

Agroforestry is a collective name for land use systems in which woody perennials (trees, shrubs, etc) are grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation or both; there are usually both ecological and economic interactions between the trees and other components of the system.

In the context of this report, the definition of herbaceous plants is taken slightly broader than only crops and pastures; also other “intercrops” that give benefits on a short term, e.g. mushrooms, shrubs, Christmas trees and coppiced trees, are taken into account as possibility to grow in association with woody perennials, which give at least part of their benefits (i.e. wood) on a longer term than the intercrops.

It is the interactions that make agroforestry systems so very complex and different from monocropping systems. Interaction takes place aboveground (e.g. shading, evapotranspiration) and belowground (e.g. root interactions with respect to water and nutrients). The more the growth habits of the intercropped species differ from those of the woody elements, the less the competition for growth resources. Agroforestry is successful when resource capture and use is more efficient (complementary) than in monoculture, leading to increased overall production (Cannell et al. 1996). But AFS may also provide environmental improvements in the long-term, e.g. resulting from erosion control or organic matter improvements, that become noticeable only after several years. The same holds for the economic aspect, that comprises diversification in type and timing of income and a possible income increase due to higher yields.

The ecological and economic output of agroforestry depends on the complexity of the system, i.e. the characteristics of the system as well as the location of the site. Consequently, there is not one single perfect agroforestry system and, moreover, agroforestry is not the panacea land use system. This in combination with the fact that their success may only be noticeable after many years makes it very difficult to predict agroforestry benefits. However, extensive evidence for their potential benefits exist (Chapter 3).

Multi-purpose tree

A multi-purpose tree is defined as a woody perennial, that is purposefully grown to provide more than one significant contribution, to the land use system in which it is grown. Multipurpose trees may be grown for products of direct economic value (e.g. wood, food-products, flowers, medicines) and/or to generate services that do not, or not directly have economic value, such as protection, nitrogen fixation, biomass-production, purification of contaminated soil or ecological functions.
**Sustainability**

Sustainability or sustainable land use has been variously defined, but the essential feature is that sustainable land use combines production with conservation of the natural resources on which production depends (Young 1997).

The formal definition of the Food and Agricultural Organization (FAO), which is commonly accepted, is as followed:

_Sustainable agriculture and rural development are defined as the management and conservation of the natural base, and the orientation of technological and institutional change, in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically feasible and socially acceptable._

### 1.5 Research aim and questions

The overall aim of this report is to explore the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands. This aim comprises four objectives:

A. To explore the general value of agroforestry and to identify appropriate tree- and intercrop species for agroforestry in the Netherlands by means of literature and internet research
B. To shed a light on governmental support and restrictions related to agroforestry
C. To assess the interest of Dutch farmers and estate owners for agroforestry and to investigate the conditions of acceptability of new agroforestry systems by means of a survey among Dutch farmers
D. Considering the results of A-C; to define constraints and opportunities for the establishment of agroforestry in the Netherlands and to propose innovative agroforestry scenarios for distinct types of land users

Below, each of the objectives is specified through several research questions. All questions refer to the Dutch situation.

**Questions for objective A**

1. What are the general characteristics of agroforestry systems that can play a role in the Netherlands and what are adequate and innovative agroforestry practices?
2. What are the possible advantages and disadvantages of agroforestry?
3. Which tree- and intercrop species are appropriate for Dutch agroforestry systems?

**Questions for objective B**

1. What are the legal constraints for the establishment of agroforestry?
2. Which subsidies (may) apply to the establishment and/or maintenance of agroforestry systems in the Netherlands?
Questions for objective C

1. What is the attitude of Dutch farmers and estate owners towards agroforestry?
   - under which conditions does agroforestry interest farmers or estate owners; i.e. what are the factors that can encourage the introduction of agroforestry systems at the farm scale (opportunities)
   - what are the factors that can discourage the adoption and introduction of agroforestry systems at the farm scale (constraints)

2. How can constraints for the introduction of agroforestry be removed or alleviated to make it acceptable for the Dutch situation?
   - which technical adaptations are needed for the introduction of agroforestry
   - which fiscal aspects need to be solved to allow the development of agroforestry systems
   - which kind and level of subsidy or other measures are needed for farmers to adopt agroforestry schemes

Questions for objective D

1. What are the major constraints for the establishment of agroforestry and how can we remove or alleviate those constraints?

2. What are the opportunities or how can we create favourable conditions for the establishment of agroforestry?

3. Regarding the constraints and opportunities, what are possible agroforestry scenarios for different types of land users in the Netherlands?

1.6 Methodology and overview of this thesis

The Chapters 2 to 5 address objective A, for which an extensive review of books, papers and web sites was undertaken.
- Chapter 2 describes the main agroforestry practices, which are appropriate and innovative for the Netherlands.
- Chapter 3 discusses the advantages and disadvantages of agroforestry systems, related to the situation in the Netherlands. This discussion is largely based on experiences with temperate agroforestry in developed countries.
- Chapters 4 and 5 give a selection of tree and intercrop species that have a good prospective for application in temperate agroforestry. The list of species is restricted to those that have proven their value in temperate agroforestry and/or species that are expected to be promising under Dutch conditions.

Chapter 6 deals with objective B and provides an overview of the restrictions of the Dutch forest law and of government subsidies, which may be applicable to agroforestry. The greater part of this Chapter consists of web-based information of the ministry of LNV (Landbouw, Natuurbeheer en Visserij)(LNV-loket 2004).

Chapter 7 addresses objective C. It consists of a summary of a farm survey, which was performed in the Netherlands within the framework of the EU-project SAFE. The purpose of the survey was to investigate the attitude of Dutch farmers and estate owners towards
agroforestry and to assess the conditions of acceptability of new agroforestry systems. The complete survey-report is attached to this report.

Chapter 8 deals with objective D and gives a synthesis of the results of the previous chapters. It discusses the implications of these results for the potential of modern agroforestry as a sustainable land use system in the Netherlands in general, and for different types of land users in particular. Several examples of possible agroforestry designs are given for each type of land user. Finally the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands will be discussed.
2. Potential agroforestry systems: characterization and main practices

2.1 Introduction

Agroforestry is a broad concept and comprises a whole range of different land use systems and practices. Agroforestry systems are distinctive types of agroforestry, at any level of generalization. Many classification systems and names are used to describe broader classes, local examples of agroforestry systems and anything in between (e.g. Nair 1993, Young 1997, Gold et al. 2000). In practice, ‘agroforestry systems’ is widely used, both in the broader sense and in the narrower sense, and the intended meaning is generally clear. Following Nair (1993), I choose to call the broader classes agroforestry practices, denoting a distinctive arrangement of components in space and time.

For the description and evaluation of systems and practices, several classification schemes have been developed. Appendix I gives an overview of the classification approach of Nair (1993), which is widely accepted. For this study, the classification criteria and framework proposed by Nair (1993) are applied in a simplified way to identify appropriate and innovative agroforestry practices for the Netherlands.

Additional criteria for the identification of appropriate innovative agroforestry practices, were that the practices should have (potential) agro-economic value (i.e. adapted to the agro-ecological and socio-economic environment), but should not yet be widely applied (i.e. on a commercial scale) in the Netherlands.

2.2 Classification of agroforestry systems and practices

Nair (1993), who thoroughly reviewed the history of agroforestry classification, summarizes four criteria for classifying agroforestry systems and practices:

1. Structure of the component: This refers to the nature of the components (e.g. tree or crop) and their arrangement in space and time.
2. Function of the system: This describes the role and output (i.e. the purpose) of the components; major functions are production and protection.
3. Agro-ecological and environmental adaptability: This is determined by the agro-ecological zones where the system exists or is adoptable
4. Socioeconomic and management level: This is based on technological input and cost and benefit relations.

According to Nair’s classification framework, the first step to classify agroforestry systems is to define their structural (nature and arrangement) and functional aspects. Subsequently the agro-ecological and socio-economic aspects are used as the basis for grouping the system practices (Appendix I)

2.3 Characterization of innovative agroforestry systems for the Netherlands

These criteria for classification of agroforestry systems and practices are considered for identifying the characteristics of agroforestry systems with prospects for the Netherlands:
Criterion 1: Nature of the components and their arrangement in space and time
Agroforestry systems always involve a perennial woody component. Depending on the nature of the other system elements (crop, pasture and/or animals) the three major categories are distinguished:

i) Agrisilvicultural, the mixture of crops and trees;
ii) Silvopastoral, i.e. trees on pastures with grazing animals and
iii) Agrosilvipastoral, the combination of trees, crops and pasture/animals.

Given the Dutch conditions, there is scope for all three categories, but mainly for the first two.

With respect to the arrangement in space and time of the agroforestry components, the spatial aspect is of major importance for the Netherlands. The spatial design directly affects the management possibilities and in particular the possible level of mechanization. A wide and linear arrangement of trees will allow the utilization of the conventional (large) machinery on intensive and/or large-scale farms. Denser or irregular arrangements will mean limitations towards mechanisation, but will have other (functional) advantages and may have potential for application at a smaller scale.

Within spatial arrangements of course also certain temporal patterns may occur, such as crop rotations, interpolation (i.e. sowing the next crop in the standing crop) and/or replacements of species. Considering the intensity of land use in the Netherlands, rotational agroforestry (i.e. the temporal separation of components) is expected to have little potential though. Rotational agroforestry, whereby arable crops are rotated with woody fallows, may be a good way to restore fertility lost during crop cultivation (Young 1997). Dutch agricultural systems, however, are very intensive and often have a high input of fertilisers, which is unlikely to change in the near future. Hence in this study, rotational agroforestry is excluded as a potential agroforestry practice for the Netherlands.

Criterion 2: Function of the system
It is striking that agroforestry with a protection function still exists in the Netherlands (e.g. windbreaks), while systems with the major purpose of production (e.g. grazed orchards) have virtually disappeared. Therefore, this report will focus on the potential for agroforestry systems, that (also) have a productive function.

Criterion 3: Agro-ecological and environmental adaptability
The Netherlands is rather homogeneous in terms of climate and relief. In this report some attention is given to system- and species adaptability to soil characteristics (soil-type, soil-depth, fertility) and to windy conditions.

Criterion 4: Socioeconomic and management level
With regard to the socio-economic and management level of potential agroforestry systems, those with low, medium and high inputs of technology are taken into account. Related to this, systems for commercial purposes, subsistence purpose and intermediates are considered as having potential for the Netherlands. Accordingly, tree- and intercrop species for various socio-economic and management levels are treated in Chapters 4 and 5.

2.4 Potential agroforestry practices for the Netherlands

Following his classification approach, Nair (1993) distinguishes between about 20 different agroforestry practices, which are denoted by their distinct arrangement of components in space and time (Appendix 1). The Association for Temperate Agroforestry (AFTA 2004, Gold
et al. 2000) in the USA, recognises only 5 categories of agroforestry practices, i.e. riparian buffer strips, windbreaks, alley cropping, silvopasture and forest farming. Other authors (ART 2004) also consider forest gardening, fertility plantings and contour buffer strips as practices for temperate agroforestry in developed countries.

Fertility plantings and contour buffer strips are irrelevant for the Netherlands. In the predominantly flat landscape, contour buffer strips, which are woody strips planted to stabilize sloping soils, would be of no use. Fertility plantings or rotational agroforestry are not considered an economically viable option for the Netherlands (Section 2.3). Windbreaks and riparian buffers are already widely applied in the Netherlands and need little exploration. These traditional landscape elements are maintained or even replanted for the purpose of protection, i.e. prevention of erosion and water pollution.

The agroforestry practices silvoarable, silvopastoral, forest gardening and forest farming may play a future role in Dutch land use and farming. These practices are innovative and suitable for the Netherlands, and will be explained below.

The classification of agroforestry systems is rather broad and complex. It may not be easy to group a certain agroforestry system within one of these major categories of practices. For instance, it may be difficult to draw a line between a complex (i.e. multi-species) silvoarable system and a forest farming system. Moreover, agroforestry systems are dynamic systems, i.e. subject to continuous changes. An agroforestry plot may start as a silvoarable system, but may change into a silvopastoral system in later years.

Nevertheless, the following description of the four considered agroforestry practices gives an impression of the range of possible agroforestry systems for the Netherlands.

### 2.4.1 Silvoarable practices

Silvoarable agroforestry or alley cropping comprises widely-spaced trees and/or shrubs associated with arable crops. Often the woody elements are planted in single or multiple rows at wide spacing, creating alleys within which agricultural or horticultural crops are produced.

In the tropics, where the term alley cropping is used, the system generally include hedges of woody leguminous species, which are regularly coppiced to provide animal feed and biomass in order to maintain/restore soil fertility. The woody component in temperate zones usually comprises species, that provide high-value timber, veneer and/or fruit and are only slightly pruned to reduce shade effects on the intercrop. Although American literature (e.g. AFTA 2004, ATTRA 2004, NAC 2004, Gold et al. 2000, Williams et al. 1997) still practices the term alley cropping for such practices, European sources (e.g. SAFE 2004, Dupraz and Newman 1997, ART 2004) tend to call them silvoarable practices, indicating the difference in function of the woody component in temperate zones. In this report the term

**Poplar with wheat (UK)**  
Source: Cranfield University

**Walnut with maize (France)**  
silvoarable agroforestry will be used. Usually annual crops are grown simultaneously with trees to provide annual income while the trees will be harvested only after several years (fruit) or decades (timber). However, perennials could also be intercropped. Winter crops (i.e. autumn-sown) are very efficient users of the light available over the dormant season of deciduous trees.

The tree component typically includes species for production of valuable hardwood and/or fruits, or desirable softwood species for wood fibre production. The trees may be grown as standards in single or double rows, as pollards or as coppice. A further alternative is a triple row, with high-value timber trees sandwiched between rows of nurse trees (usually coniferous) which help train straight trees and are themselves thinned at a later stage (ART 2004).

Small scale growing of vegetables in orchards were common practice in temperate zones, but recently modern mechanized silvoarable systems are gaining increasing interest as an alternative land use system in the United States, Canada and Europe (e.g. SAFE 2004, ART 2004, ATTRA 2004, NAC 2004, Garrett and McGraw 2000, Dupraz and Newman 1997).

2.4.2 Silvopastoral practices

A combination of trees, forage (pasture) and livestock production is called silvopastoral agroforestry. The system is designed to produce a high-value tree component, while continuing production of the forage component indefinitely or for a significant time.

The forage component usually consists of a permanent pasture, mostly grazed rotationally to allow regrowth and prevent tree browsing. In early years, the grassland can also be cut for hay or silage (this is actually a silvoarable practice). White clover, which is a rather shade-tolerant legume, is often included in the mixture.

Trees are grown as standards or as pollards, in single or multiple rows. These may be trees for timber, fibre or fuel wood, fruit or other valuable products. Nitrogen-fixing trees can be useful to supply nitrogen for the forage crop. Trees may also be maintained to provide shade, shelter and fodder for the animals, but for regions characterized by a highly modern and intensive agriculture (high input), which generally holds for the Netherlands, highly valuable trees will be necessary to be economically viable.
The trees are usually protected by some kind of shelter (e.g. a plastic tube or net), especially when trees are young (Section 5.2.3.3).

Silvopastoral agroforestry is a common traditional system in the Netherlands, for instance fruit orchards with sheep. Although much of the old practices were lost during intensification, modern silvopastoral systems are proving their value in temperate countries as the USA, the United Kingdom and France. Recently a few examples of modern silvopastures can also be found in the Netherlands (Oosterbaan et al. 2004).

Modern silvoarable and silvopastoral agroforestry systems are often similar in terms of tree species, tree spacing and tree function. Within a tree life cycle the system might be changed from a silvoarable to silvopastoral system, when crop yields are no longer economically remunerative.

2.4.3 Forest gardening

Temperate forest gardens are comparable with the home gardens in the tropics, where they often form a major part of the food producing system on which the rural people rely since ancient times. In temperate regions, forest gardens are quite a recent innovation, that has been inspired by the efforts of the British forest gardening pioneer Hart (1996).

A forest garden is a multi-species and multi-storied dense plant association, based on the coexistence of trees, shrubs and perennial plants. The different species are planted and/or managed in such a way that they mimic the structure and the ecological processes of natural forests. It is assumed that the local natural forest structure is the most stable and sustainable type of ecosystem in the given environmental conditions.

A forest garden is organised in up to seven layers, i.e. canopy trees, small trees/large shrubs, shrubs, herbaceous perennials, ground covers, climbers/vines and root crops. Within these layers, the positioning of species depends on many variables, including their requirements for shelter, light, moisture, good/bad companions, mineral requirements, pollination and pest-protection. Forest gardening may start with native forest trees, especially ones that produce fruit, nuts, or sap for syrup.

In temperate regions, the light conditions are much more limiting than in the tropics. Therefore, the species for the upper- and understorey layers must be chosen carefully. Usually, much use is made of shade tolerant plants, whereas light demanding crops are planted on the more open spots. The crops that are grown may produce fruits, edible leaves, spices, medicinal plant products, poles, fibres for tying, basketry materials, honey, fuel wood, fodder, mulches, game, and juice. A well-established forest garden can be virtually self sustaining and, when plant mixtures are appropriately selected, may be essentially free of pest and diseases (Hill and Buck 2000).
Forest gardens are often applied at a small scale within the permaculture movement, since they address sustainability, can be very productive and provide a variety of products, all at a low maintenance cost. Moreover, a well-designed forest garden can provide a certain degree of self-sufficiency. The main drawback of this system is that the establishment requires a large number of plants (high investment costs) and substantial work (high labour costs).

2.4.4 Forest farming
Forest farming is the cultivation of edible, medicinal or decorative specialty crops as understorey in (semi)natural woodlands. This means that when a (semi)natural forest is used for wood production and additional production, it becomes an agroforestry system. Forest farming does not include the gathering of spontaneously-occurring plants from native forests, which is called wild crafting.

In forest farming, the high-value specialty crops are cultivated under the protection of a forest canopy that has been modified and managed to provide appropriate conditions. It is a way of utilizing forests for short-term income while high-quality trees are being grown for wood products. The amount of light in the stands is altered by thinning, pruning, or adding trees. Existing stands of trees can be intercropped with annual, perennial, or woody plants.

Typically, a forest farm can be established through thinning an existing forest to leave the best trees for continued wood production and to create conditions for the understorey crop to be grown. The understorey crop is then planted and managed intensively to provide short-term income. Areas used for forest farming are usually small and systems usually focus on a single crop plus timber, but can be designed to produce several products.

The cultivation of medicinal herbs (e.g. ginseng) or gourmet mushrooms under forest conditions are common practices of forest farming in the US and Canada. In Europe however, forest farming seems to be little known and practiced.
3. Advantages and disadvantages of agroforestry

3.1 Introduction

Below an attempt is made to outline the potential advantages and disadvantages of agroforestry, which may occur in the Netherlands as a consequence of ecological and socio-economic factors. This summary of advantages and disadvantages will be illustrated with examples from literature. Often constraints for agroforestry can be removed or alleviated by choosing appropriate plant species, system design and management practices. General methods to counteract disadvantages will be discussed. However, it must be realized that it is very difficult to generalize advantages and disadvantages of agroforestry, which is a complex and dynamic land use system, in biophysical and economic terms. Biophysical and/or economic performances of similar agroforestry practices may vary with soil- and climatic conditions, subsidy regulations, price fluctuations and the socio-economic situation. A certain tree feature (e.g. being the host of insects), might be beneficial to the crop (tree hosts predators of crop pest) or disadvantageous (tree hosts pests of crop). Moreover, the output of a certain system changes with time. The long time horizon of agroforestry and the lack of experimental data (in particular over an entire agroforestry life cycle) form further difficulties for prediction of agroforestry benefits.

Hence this chapter should be understood as a guide for identifying the advantages and disadvantages that may occur in agroforestry in the Netherlands. The examples given in this chapter are useful to consider when designing a new agroforestry system.

Modern temperate agroforestry is an emerging technology and some uncertainty is associated with its adoption. Consequently, operators considering implementation of an agroforestry field should consider all potential advantages and disadvantages and evaluate the risks associated with its practice given the local conditions.

3.2 Advantages of agroforestry

Research findings indicate that modern agroforestry systems can be environmentally friendly and economically profitable. The association of high quality timber or multipurpose trees with arable crops and/or grazed pastures may i) improve the sustainability of farming systems, ii) increase resource capture and system yield, iii) diversify farmers' incomes, iv) provide new products to the wood industry, and v) may enhance biodiversity and create novel landscapes of high value (SAFE 2004).

The first part of this paragraph deals with the potential ecological and environmental advantages of agroforestry in The Netherlands. The second part treats the possible socio-economic advantages, part of which are a direct result of the ecological advantages.

3.2.1 Ecological and environmental advantages

Biodiversity and landscape quality
In agroforestry, the incorporation of multiple species into production systems, intrinsically results in a high biodiversity compared to monocultures. In monocropping, ecosystems are extremely simplified by human manipulation to favour the production of a single plant species, creating unsuitable and/or unattractive habitats for most wildlife species. For
intensive timber plantations often the same applies. Agroforestry systems, through multi-
species and structural diversity, add complexity to agro-ecosystems, bringing them closer to
nature. Such systems can be seen as interface between nature and agriculture, providing
new niches and opportunities for wildlife that do not exist in monocultures. Various studies
show that natural fence lines, windbreaks and intercropping systems act as important refugia
and corridors for wildlife and show increased numbers of animals such as birds and insects
and small mammals (Williams et al. 1997).

Through the inclusion of trees in agricultural fields, the landscape does not only become
more attractive for nature, but also for people. Most people appear to appreciate a diverse
landscape. The presence of agroforestry fields makes agricultural landscapes more diverse,
increase their aesthetic and recreational value and hence raises their overall landscape
value.

Efficient use of growth resources
One of the major arguments for agroforestry is the fact that a mixed system of trees and
crops might make use of resources as light, water and nutrient more efficient than a
monoculture. The reason is that mixed systems use the resources differently in space (e.g.
deep tree roots and shallow crop roots) and/or time (e.g. walnut starts to intercept light after
the winter crop is already far developed, so that shade is not a constraint).

Research suggest that the roots of trees in agroforestry systems can form a safety net,
catching water, nutrients and even pesticides (Garrett and McGraw 2000, SAFE 2004,
Dupraz pers.comm. 2004, INRA, Montpellier). This network of roots may capture vertical and
lateral nutrient-flows and greatly reduce their loss from the system (when trees are in leave).
This means an increased efficiency of resource use, which may result in increased
production (Section 3.2.2).

As resources are used more efficiently, less resources as water and agrochemicals may be
required, to the benefit of the overall environment. Furthermore more biomass (i.e. products)
may be harvested from an agroforestry field, than from an equal surface of a monocrop, i.e.
the LER\(^2\) will be higher than one (Section 3.2.2). This means that with agroforestry less land
surface may be required to produce the same yield, leaving a larger area for other purposes.

Microclimate
It is often assumed that trees will negatively affect crop performance due to shade effects.
The positive effects of trees on the microclimate, which may improve the crop performance,
are however often forgotten.

Through shade and wind reduction the microclimate in agroforestry systems will differ from
that in monocropping systems. The impact of windbreaks on microclimate has been studied
extensively. The system design as well as tree and crop height are important factors for the
actual change in microclimate. Whether the modified microclimate benefits the crop
development and production is also dependent on local climate and the crop species and
crop phenological stage.

In the Netherlands, predominant winds are coming from the west and therefore a north-south
orientation of tree strips gives most wind-protection. In addition to the geometrical

\(^2\) The Land Equivalent Ratio (LER) is the ratio of the area needed under sole cropping to the area of
intercropping at the same management level to give an equal amount of yield. LER is the sum of the
fractions of the yields of the intercrops relative to their sole crop yields (FAO definition).
arrangement and tree height, the tree shape and density of the tree crowns in a line have an impact on the degree of wind speed reduction.

Pollard et al. (1979) conclude, based on a large number of experiments with different types of hedge-like shelters in different countries and climates, that wind speed can be reduced up to 60% on the leeside. This results in a reduction of soil evaporation by up to 30% and soil moisture increase of up to 20%. The average soil temperature can be 10-15% higher on distances up to 6-8 times the height of the woody element. Brandle et al. (2000) mention that windbreaks with a density of 40-60% density (i.e. the ratio of the solid portion to the total volume of the windbreak) provide the greatest reduction in wind speed across the greatest distance. Few data are available on windspeed reduction in modern silvoarable and silvopastoral systems (single or multiple tree rows), but similar results may be expected.

A reduced air flow in the field induces lower evapo-transpiration and higher air and soil temperatures. In the Netherlands such changes should usually enhance crop performance. The change in microclimate could benefit the development of crop pests on the one hand and that of their enemies on the other.

Yields for grain crops, horticultural crops and orchards have been shown to increase with protection of wind in temperate regions (Williams et al. 1997, Brandle et al. 2000). The Agroforestry Research Trust (2004) indicates that wind-protection may result in up to 25% increases in production and also increases bee pollination. Boer and Oosterbaan (2004) mention that cereals, maize and sugar beets give higher yields on wind-protected sites. Fruit trees, but also horticultural crops are known to profit from decreases frost-damage. Hay and silage grass will dry slower in shade and can loose some of their mineral value.

Oosterbaan et al. (2001) mentions that the quality of pasture may decrease as a result of a shift to more shade tolerant grass-species due to decreasing light levels in aged agroforestry systems. Sharrock (1997) however, makes notice that forage growing under the shady, low wind environment near trees tends to mature more slowly and therefore, be lower in fibre and more digestible than that growing out in the open. Studies in Ohio and Missouri (USA) both demonstrated increased yield and quality (digestibility) of various grass forages grown under black walnut (Williams 1997).

The warmer microclimate in agroforestry systems may thus result in higher yields and/or quality of the intercrop. Rough-and-ready rules on the effects of the microclimate are hard to give though (van Wingerden et al. 2004).

Pests and diseases
Interactions between wildlife and farming systems can be positive but also negative, since the overall effect depends on the set of system characteristics. Some promising strategies for pest control may be achieved when the woody element is the host of a predator of a crop pest. This type of benefits arising from trees in arable land have been often overlooked. However, care has to be taken when choosing the tree species, since it might also host the pest. Certain aphids are known to use woody vegetations to survive the winter (Boer and Oosterbaan 2004). Furthermore trees can also create the right circumstances for pests and diseases. Potatoes for instance, may produce much less under the influence of tree plantings, due to Phytophtra and other diseases. Shade may give fungi more chance, decreasing the quality of crops that have to dry or ripen (Boer and Oosterbaan 2004).

Recent studies reveal that significant benefits may be provided by biocontrol agents of insect pests in or near wooded field corridors (Williams et al. 1997, van Wingerden et al. 2004). Van Wingerden et al. (2004) preliminary conclude that the chances of Green-Blue Veining (i.e. land and water non-crop elements) providing good conditions for pest control by natural enemies exceeds its risks as a source for pest outbreak. As such they consider the pest controlling functions of these Green-Blue Veins as a life support function, as a service from
nature to agriculture. Research indicates that small scale landscapes and plots narrower than 100 m (between woody elements) form the best habitat for natural enemies (van Wingerden et al. 2004). This suggests that the presence of woody elements can be beneficial for the intercrop in terms of pest control. Furthermore rows of trees can form natural barriers between the intercropping strips, hindering the spread of diseases. On the other hand, certain tree species could be also be the host of the crop pest. Whether trees favour pest control or pest infection depends also on their impact on the microclimate in relation to potential crop pests.

Erosion and water quality
In many parts of the world agroforestry is primarily applied as a mean of erosion control. Since the Netherlands are rather plane, water erosion is restricted to some small areas in the south. Wind erosion, on the other hand, is known to be quite severe in the northern Netherlands, such as the Flevopolders. Millimetres (or tons) of topsoil are blown away every year, which means a loss of nutrients and often already scarce organic matter. Through the reduction of windspeed through trees, wind-erosion will be decreased (ART 2004, Brandle et al 2000), which indirectly will have its beneficial impact on the farm economy.

In the Netherlands, another major problem is groundwater pollution and eutrophication of water bodies as a results of the leaching of nutrients and agrochemicals from agriculture. As mentioned before, tree-roots in agroforestry systems can form a safety net, catching nutrients and pesticides (Garrett and McGraw 2000, Dupraz pers.comm. 2004, INRA, Montpellier), resulting in decreased groundwater and surface water pollution. Reductions of 70 % and more in contaminants such as nitrates are reported from the use of vegetative buffer strips along streams (Garrett and McGraw 2000). Although these strips are usually wider than those used in silvoarable and silvopastoral systems, the cumulative effect of several narrower strips may still result in filtering out a reasonable portion of the contaminants. It must be realized however, that tree roots will capture few nutrients as soon as they have shed their leaves, which is actually the season when leaching is usually greatest.

3.2.2 Socio-economic advantages

Diversification of income sources
Dutch agriculture is under pressure. Recent epidemics of animal diseases combined with government policies make it hard for farmers to make a living. Dutch farmers generally apply to two contrasting solutions. They either choose for a further intensification, specialization and mechanization or they prefer to extensify and diversify their farm income.

For this last group, agroforestry could be a suitable option. Agroforestry gives farmers the opportunity to spread their income and risks over different products and with time. Furthermore well chosen agroforestry combinations may result in a better spread and more efficient use of labour and machinery. At last, many agroforestry systems and their products lend themselves for value adding activities. Depending on individual preferences, farmers could for example choose to produce high-value specialty products for niche markets.

In general it is expected that demands and hence the prices for temperate hardwood will rise in the future. The reasoning behind this is that there is an increasing demand for hardwood, while imports of tropical hardwood will be more and more restricted. Also the demand for biomass production for fuel, fibre and waste management are expected to rise. The stronger the pressure on the price development of arable productions, the more attractive agroforestry will become as an economic alternative to conventional farming.
Production
Apart from diversification of income, agroforestry systems may have direct economic advantages. It gives landowners the opportunity to maintain a crop, while establishing trees on their land. The economic advantages are often difficult to predict due to the long time horizon of agroforestry systems and a lack of mature examples in Europe, but there is evidence that well designed agroforestry systems can be economically beneficial, when the LER is above 1 (Williams et al. 1997, Dupraz and Newman 1997, Huang 1998). Dupraz and Newman (1997) for example mention that with intercropping radishes in a pear orchard LER values of 1.65 to 2.01 were found, relating to economic and biomass yield respectively. Huang (1998) found LER values between 1.2 and more than 2.0 during the first five years of intercropping Taxodium ascendens with rape, wheat and soybean. Williams et al. (1997) mention the Ontario fruit producers, who routinely grow vegetables between their trees during the early years of orchard development. The advantages of their practices are clear: early returns, improved access to markets (diversification), better utilization of labour and equipment. The early benefits to fruit production included earlier production, larger early crops and higher quality early produce.

Such benefits can be attributed to cultural benefits associated with intercrop production (e.g. spraying for weeds and pests, irrigation, fertilisation). The tree might also capture some of the fertilizer. Through ploughing and underground competition with the intercrop, trees are forced to root more deeply, which is an advantage in drier periods (SAFE 2004, Dupraz pers.comm. 2004, INRA, Montpellier). In this way management practices for the intercrop ameliorate the growth of trees, leading to increased wood production and/or earlier yields (Huang 1998). In AF, a more efficient use of growth resources and an improved microclimate may also enhance yields and/or quality of the intercrop (Section 3.2.1).

Indirect economic benefits
Agroforestry practices may reduce the costs for labour and chemical input by suppressing weeds and pests. For instance, the tree might be a host of predators of crop pests and the intercropping of tree alleys decreases the weed problem heavily compared to a pure forest stand. Trees in agroforestry systems may benefit from the crop fertilisation, weeding and irrigation increasing wood and/or fruit production (Section 3.2.1).

Animals often show to appreciate trees for their wind-protection and shade. Trees have a climate stabilizing effect and reduce wind-chill and heat-stress. As such trees not only contribute to the well-being of the livestock, but may also have an economic advantage. Heat-stress for example is known to severely decrease milk production and quality. During cold-spells, protection from trees can cut the direct cold effect by 50 percent or more and reduce wind velocity by as much as 70 percent, making livestock require less feed energy (Clason et al. 1997, Williams et al. 1997). In both cases the livestock’s performance is improved and mortality is reduced.

Last but not least, the presence of woody elements usually enhances the landscape value (Section 3.2.1). The park-like landscape of wide spaced and well managed trees on arable land would be more attractive for recreation than the current open, for the eye rather monotonous Dutch countryside. Hence agroforestry may impede financial benefits through rewards from recreation and tourist activities. Examples are farm camping or lodgings, subsidies on tourist trails, fees on self-picking of fruits.
3.3 Disadvantages of agroforestry

The main possible disadvantages of agroforestry can be divided into negative ecological interactions between components, as competition for above- and belowground resources, and socio-economic disadvantages.

3.3.1 Negative ecological interactions

As explained in Section 3.2.1 the efficient use of growth resources is the basis of agroforestry. However, competition for above- and below-ground resources is often seen as the major constraint of mixing trees and crops. Therefore this section will treat on these aspects and the opportunities to minimize competition and optimize the use of growth resources. Further ecological disadvantages that could occur are increased pests and crop damage by animals as attracted by the presence of trees.

The below is divided in competition for light and for water and nutrients respectively, but it must be kept in mind that all growth factors are interacting and it is difficult to predict the net effect of trees on crops and vice-versa on a single factor.

Competition for light

Competition for light is often seen as a major problem, in particular in the Northern European countries. The degree of light competition depends on the incoming radiation as well as the tree architecture and the light requirements of the crop. For a given location, the problem of light competition can be approached either from the tree side or from the crop side.

A light demanding crop should be chosen only as long as the trees shade is tolerable and/or the crop production is still economically interesting (Paragraph 5.2). As soon as trees cast too much shade, more shade-tolerant or even shade-demanding intercrop species could be grown (Paragraph 5.3 – 5.5).

The tree architecture comprises tree height, canopy size, form and density and leaf angle distribution. These characteristics differ between species. For agroforestry systems, the wide spaced planting of trees with open and slowly developing crowns at sufficient distance to the adjacent crop will facilitate the light interception of the crop.

In addition to an appropriate combination of tree and crop species the farmer can manage tree shade by canopy pruning and tree thinning. If this is not sufficient the farmer might increase the distance of the crop to the tree line (narrower intercrop strip) (Dupraz and Newman 1997) or replace the crop by a shade tolerant one or stop cropping. The pruning can be to a smaller or a larger extent, depending on the shade situation.

Experiments with various pruned poplar-hybrids, planted at 10 m x 6.4 m, showed an average light interception of about 40 % after 11 years, leading to no yield reduction of intercropped faba beans as compared to the control (Pasturel 2004). Pruning of lower branches up to a height of at least one log length (>2 m) has also proven to be a profitable solution to log quality where processors are willing to pay a premium for large, knot free-logs. This type of pruning produces an open park-like forest which is visually pleasing to neighbours and visitors (Section 3.2.1).

Competition for water and nutrients
Belowground studies are difficult and laborious and little research is done on the underground interactions between trees and crops. Most information on belowground interactions are obtained from measurements of soil water content and plant growth (comparison of yields in monoculture and mixed stands).

According to Dupraz and Newman (1997) trees in agroforestry usually grow slower than in a forestry control plot where trees are sprayed with herbicides on a 1-m radius, but they grow faster than in an unweeded forestry plot. Mayus (pers.comm. 2004, and Weed Ecology Group, Wageningen) however, remarks that this may only be true for initial growth. After some years (7 for poplar) the trees in agroforestry might grow faster than in monocultures, as was found in poplar-wheat mixtures in the South of France. In AFS in dry areas, perennial fodder and cereal crops appear to heavily reduce tree growth compared with that of agroforestry trees on bare (weeded) soil, but the growth is not significantly less compared with forestry controls (Dupraz and Newman 1997). Gold and Hanover (1987) give various examples of trials in which tree growth was higher with tillage and intercropping compared to stands with tillage alone. Also Dupraz and Newman (1997) mention findings of quicker tree growth in the first three years in agroforestry plots than in unweeded forestry.

The optimum maintenance within the tree row once the trees have been established is still unclear. The common practice is continuous weed control by various combinations of plastic mulch, herbicides and tillage, or the establishment of a low competition ground cover (Dupraz and Newman 1997).

Much of the underground competition will depend on root architecture. For agroforestry it would be most profitable to combine trees and crops that have different root architecture, for example deep rooting trees and superficially rooting crops. But most trees, when conditions allow this, develop a superficial root system, as crops do. Sharrow (1997) however notes that lower densities of trees and planting patterns in which trees have one or more sides in the open, typically used in agroforests, promotes rapid growth of trees and such trees may have greater taper than trees growing in closed canopy forest. This may mean that trees grown in agroforestry will more easily reach deeper soil layers, resulting in less underground competition. Dupraz (pers.comm. 2004, INRA, Montpellier) suggests that by intensive tillage, tree roots in the top soil will be laterally pruned each year and forced to grow in deeper soil layers. Consequently, the trees have access to water in deeper layers than the crop, reducing underground competition. Even more effective than tillage is ripping the outer edge of the tree line. In a similar way, root competition may also be alleviated by digging trenches between the trees and the crops.

In a mature silvoarable system in France (poplars and wheat), provisional results show that winter crops induce an unusual deep rooting pattern for the trees that help them to face the summer drought (SAFE 2004). Deep tree roots can form a web under the crop, that efficiently capture water and nutrients that would otherwise be lost by leaching and lateral waterflows (i.e. tree roots acting as a safety net)(SAFE 2004, Dupraz pers.comm. 2004, INRA, Montpellier). In case of drought, such trees will suffer much less from drought than more superficial rooting forest trees.

Research on 11 year old poplars showed that the root system was vertically and laterally well developed, suggesting that it would be less affected by water shortage than an annual crop (Pasturel 2004). Pasturel (2004) suggests to use wintercrops that develops a root system just after tillage, allowing the crop to establish before the tree roots begin to grow in spring. In this same experiment with poplar and faba beans the number of pods per plant and number of seeds per pod of the intercrop near the tree was reduced, probably due to competition for water and nutrients between trees and crop (light penetration was quite evenly distributed). However, averaged over the whole alley, there was no difference in number of pods per plant and number of seeds per pod between the silvoarable experiment
and the control crop area. It can be concluded, that the higher crop yield in the middle of an agroforestry alley compensated for the losses near the trees. This could be due to more favourable growth conditions (i.e. decreased intra-specific competition) in the middle of an agroforestry alley than in a monoculture, e.g. lower soil water loss by evapo-transpiration.

Because of their growth potential and long growing season, cool season forages (grass, clover, alfalfa) can be highly competitive with tree crops and able to greatly reduce tree growth, especially of newly planted trees (Dupraz and Newman 1997, Sharrow 1997, Garrett and McGraw 2000). A commonly used approach when planting trees into established forages is to spray a strip or circle around trees to provide a competition-free zone around each tree. Otherwise, by using annual intercrops for the first 3-6 years and consequently ploughing the intercrop area before planting the crops during these years, trees will form deeper roots during that period and may be little harmed by competition if a forage is established after that period (Section 5.2.3.1). Once trees overtop the crop and establish deep roots beneath the crop rooting zone, competition is largely one-sided, with trees possibly reducing under storey production, but under storey having little effect upon the trees.

Fruit trees are known to have a critical period for diameter growth to obtain good production. Hence initiation stages in fruit trees are very sensitive to competitive stress (Section 5.2.3.1). Timber-producing silvoarable systems may be more resilient to competition stress and that is amongst the reasons (see also Section 3.3.2) why future changes in silvorable designs from growing fruit trees to growing timber trees are predicted (Dupraz and Newman 1997).

In the Netherlands, where water (high and well distributed rainfall) and nutrients (high level of fertilisation) are generally not limiting, below-ground competition between trees and crops are expected to be small or even negligible. But in agroforestry systems on pure sandy soils and/or with low input, competition may be crucial, in particular in dry periods. Under such farming conditions, it is suggested to increase the width of the tree strip (i.e. increase distance tree-intercrop). This will result in decreased above- and belowground competition and hence in more constant square meter yields of the intercrop (Dupraz and Newman 1997).

3.3.2 Socio-economic disadvantages
In particular in countries as the Netherlands, where modern agroforestry is virtually unknown and as such not yet acknowledged, many socio-economic constraints can be expected. The following summarizes the major socio-economic factors, which may be disadvantageous for the implementation of agroforestry systems in the Netherlands.

Grants/subsidies
Even though the production of agroforestry may be higher than that of monocropping systems (Section 3.2.2), the economic output of a land use systems can vary enormously with the availability of grants. The available grant schemes in Europe are designed for forestry or agriculture, whereas agroforestry is not recognized. Moreover, the status agroforestry field does not yet exists. In contrast in France, new regulations allows farmers who plant trees in an agroforestry system to get compensatory payments for the uncropped area below the trees³. Additionally in 2001 the French government introduced an agri-environmental measure⁴ that provides an incentive for farmers who manage agroforestry systems. The payments compensate farmers for the additional costs due to the trees. It was officially approved by the STAR Committee of the EU on 21 November 2001 and is valid for both silvoarable and silvopastoral systems. It is an additional five-year payment to cover the

⁴ Mesure No 2201 et 2202 Creation (2201) et Gestion (2202) d’Habitats Agroforestiers, AEM National Francaise Agroforesterie Valideé
costs of forming an agroforestry system of at least 50 trees/ha, and the payment is equivalent to €240/ha/yr for trees with crops, €240/ha/yr for trees with sheep and €362/ha/yr for trees with cattle.

These regulations have resulted in an increased establishment of agroforestry systems (Liagre, pers.com 2004, Ministry of Agriculture, Paris). Also in the Netherlands farmers and estate owners, particularly those with extensive farming systems, were interested to experiment with modern silvopastoral systems when local subsidies and compensations were made available (Oosterbaan 2004).

In other European countries, including the Netherlands, unfavourable grant/subsidy regulations currently often make monocultures economically more attractive than agroforestry systems. Edelenbosch (1994), for example, found that without any grants intercropping of poplars with maize, sugarbeets or grass would result in considerably higher net profits compared with poplar-monocultures. At present, however, the planting of fast growing trees in monocultures is subsidized, while planting them in agroforestry is not. This makes poplar in agroforestry economically less profitable than in a pure poplar stand.

However, there may also be examples, where agroforestry is economically viable under the current situation. Oosterbaan (2000) calculated that walnut orchards with cattle grazing the grass-intercrop would give a higher net benefit over 40 years than a grass monocrop, even when a management subsidy is received on the grass monocrop. Since modern agroforestry plays not yet a role in the Netherlands the eligibility of grants/subsidies have not yet been investigated. Eventually there are some existing national and regional subsidies, that apply on specific agroforestry practices. The latter will be discussed in more detail in Chapter 6.

Mechanization and labor
Difficult application of machinery, is often seen as a major problem of agroforestry systems. In modern AF, trees are typically arranged in lines at a certain distance. The distance between tree lines should be large enough to allow efficient use of the usual machinery. Machinery should be given plenty room, otherwise chances are higher to damage or even pull out trees (Swellengrebel 1990, Oosterbaan 2004). It may even be necessary to choose for a wider spacing than initially necessary, keeping in mind the future purchase of bigger machinery. If the agroforestry design and the machinery are synchronized however, mechanization in agroforestry will have little limitations.

Usually a crop free zone of one to two meter is kept on either side of the tree line and the lower branches are pruned. This not only allows the machinery to pass through easily, but also reduces competition. Furthermore it is important to reserve enough space at the headland to allow machinery to easily turn in and out of the intercrop strip between the trees, otherwise turning takes too much time and trees may be damaged (Swellengrebel 1990). Dupraz and Newman (1997) suggest a 14 m distance between the tree rows in experimental designs, as this would accommodate most of the mechanization constraints and allows for a 1-2 m bare strip along the trees. For intensive commercial farms a larger spacing (20 to 30 m for the Dutch situation) may be required, regarding the usual width of machinery.

In silvopastoral systems, where forage is also harvested for hay or silage, trees and individual tree shelters (if present) will mean a little yield loss and a lower labor-efficiency, since one has to circle around the trees. Oosterbaan (2004) found that higher tree densities have higher harvesting costs, higher yield loss and more tree damage than lower densities. Also in silvoarable systems, trees may mean that measures as ploughing, weeding, spraying and harvesting take more time per square meter of intercrop. On a hectare basis, it may take less time though, since a strip along the tree rows is usually passed over. Unknown is how contractors, who are usually paid per hectare, will react on agroforestry systems and the
possible increase of labor/ha related to that. Establishment, thinning, pruning of trees and transport of the wood will also take time, but this can be done in the quiet season and is less bound to specific times or weather conditions than other agricultural activities as ploughing, sowing and harvesting (Swellengrebel 1990).

If the agroforestry system consists of fruit or nut trees, harvesting of these fruits/nuts may also mean extra labor, especially in case of unmechanized harvesting. Furthermore the picking of fruits/nuts may limit the intercrop practices. Nuts for example will fall on the ground in autumn and can not be picked when an intercrop is present. Mechanical picking has proven to work best on grass (Section 4.3.1). For this and other reasons (see also Section 3.3.1) Dupraz and Newman (1997) predict that future changes in silvoarable designs will probably see a shift from growing fruit trees to growing timber trees.

In complex systems as forest gardens and certain forest farming systems mechanization is virtually impossible and can thus be quite labor-intensive. Especially the establishment of such systems will demand considerable efforts. Current practices indicate that they therefore usually take place on a relatively small scale (Hill and Buck 2000, ART 2004).

Finally many agroforestry systems will require an entrepreneurial attitude of the farmer or landowner. Since markets for many agroforestry specialty products will be small or undeveloped, the agroforester may have to locate or develop potential markets, e.g. local stores, restaurants, cooperatives (Josiah 1998). Furthermore also gaining information on production and processing of new products, i.e. technical expertise, may take time.

Investments
The development of agroforestry systems generally require high investment costs, which do only pay back on the long term. Good planting stock, tree-protection (individual tree shelters or fencing) and the labour needed for establishment are initial investments. The purchase of machinery, for example for pruning or picking of nuts, may be a secondary investment. An indirect investment is also the decreased benefits of the crop due to the occupation of productive land by trees, of which the economic returns only come in a later stage. It may be difficult for farmers, who are used to quick returns on investments, to make such long term investments.

Markets
Marketing of products from agroforestry systems may be a problem for farmers. Wood, fruits, nuts and other agroforestry products will perhaps be new for farmers and so is the marketing of these products. The agricultural sector is used that the marketing of agricultural products is perfectly regulated through cooperation of different companies for buying, transport and processing of the products and the selling of the final product. Such clear and organized marketing chain does not exist for the marketing of relatively small amounts of wood and other non-conventional agroforestry products.

Furthermore markets for certain agroforestry products may be limited compared to conventional arable products. This makes good market research and/or development necessary before investing in large scale production of such products. Related to the disadvantage of long term investments, investments in tree planting also means dependency of future markets. If the market for walnut production seems to be good now and prices are high, all may change if 100 other farmers also decide to invest in walnut production. Cooperation within the marketing chain and guaranteed prices as described above could also prevent such problems.
On the other hand, many of the possible (new) agroforestry products give innovative farmers the opportunity to diversify, to create new niche markets and to set up their own (short) market-chains. Furthermore, as mentioned before in 3.2.2, the perspectives for temperate timber are good.
4. Trees for temperate agroforestry systems, in particular the Netherlands

4.1 Introduction

In the Netherlands, an optimum tree species for agroforestry should meet the following criteria:
1 economically profitable in the relatively short term
2 adapted to the local circumstances
3 compatible with the crop- and/or livestock component

These criteria were applied for the selection of tree species that could fit in Dutch agroforestry systems. The selected tree species are described in this chapter.

The first criterion is based on the assumption that farmers usually have a short time horizon and they are used to relatively fast returns on their investments. Moreover the timber harvest of very slow growing tree species (50 and more years) would be outside the economic lifetime of many land holders. It is expected that tree species, which give early returns will be preferred by Dutch farmers and hence are most easily adopted (Chapter 7). Therefore this chapter focuses only on two groups of trees with potential for Dutch agroforestry:
- fast growing tree species that give relatively fast revenues from poles and wood
- slow growing species that, apart from their wood, provide secondary products in the short term, so called multi-purpose trees

First paragraph 4.2 lists trees with fast (juvenile) growth, which may be suitable for short- and mid-term rotations in Dutch agroforestry systems. In paragraph 4.3 a description is given of multipurpose trees that have proven their value and their suitability to the Dutch environment. A distinction is made between upper-storey and lower-storey trees. Upper-storey trees are trees that need full light for good production. Lower-storey trees are usually small trees, which tolerate (partial) shade. This makes them suitable for planting under larger trees. Finally paragraph 4.4 introduces multipurpose species that are not yet cultivated on a commercial scale in the Netherlands, but that have a potential for Dutch agroforestry mainly due to their secondary products. These will be called specialty trees. Again the species are distinguished between lower- and upper-storey trees. When possible the tree description includes information about the tree properties and demands in terms of their suitability for agroforestry in the Netherlands (i.e. if they fulfill criteria 2 and 3).

4.2 Fast growing trees

4.2.1 Short rotation trees

Short rotation trees are characterized by a fast growth, resulting in a wood of generally low density and value. Depending on the species, environmental conditions and wood utilization the tree life cycle comprises 10 to 30 years for poplar, willow and alder (Oosterbaan 2000).
**Populus spp. (Poplar)**

Poplar is probably the most cultivated short rotation tree in temperate agroforestry systems, e.g. in Great Britain, France, Italy, China and N-America. Poplars have always been important because of their fast growth, ease of reproduction and desirable tree shape. Production capacity, tree shape and vulnerability for diseases may greatly differ between various cultivars. According to Kuipers (pers. comm. 2003, Stichting Bos en Hout, Wageningen), a crossing of *Populus deltoides* and *Populus nigra* is useful in the Netherlands, but good results are also reported with hybrids of *P. trichocarpa* (e.g. Pasturel 2004, Burgess et al. 2003).

Poplar grows on rich sands, sandy loam, light and heavy clays with a groundwater level lower than 50 cm in summer (Oosterbaan 2000). Site selection has proven to be very important for attaining optimum yields (Burgess et al. 2003). Poplars are reported to be able to develop very extensive and aggressive root systems that can invade and damage drainage systems (PFAF 2004). Although shade effects can be reduced considerably by pruning the lower branches (Pasturel 2004, Burgess et al. 2003, Dupraz and Newman 1997) it must taken into account that the shade effects of poplar may be high compared to many other trees of the same age. Nonetheless it is frequently applied in agroforestry systems in temperate zones and good results are reported (e.g. Pasturel 2004, SAFE 2004, Dupraz and Newman 1997). An example are the trials of mixed tree and crops at two Universities in Britain, at Leeds and Cranfield. The mixed cropping system showed higher productivity than monocultures, due to more efficient use of light, nutrient and water. The crop development of for instance wheat was much advanced by the time that the poplar leaf area was fully developed, while water and nitrogen competition appeared to be low too. The reason for the latter is most likely that the trees’ uptake of water and nitrogen occurs at deeper soil depths than that of the crop (Wainwright 2004).

**Salix spp. (Willow)**

Willow has similar properties as poplar and has the advantage that it can grow on soils with high groundwater tables, making it especially suitable for spots in the Dutch polders where other trees are difficult to grow. It grows on wet sands, sandy loam and light clays with a groundwater level lower than 30 cm in summer (Oosterbaan 2000). A disadvantage of willow is its vulnerability for the watermark disease, especially from age 15 onwards (Oosterbaan 2000). Coppicing or pollarding decreases the risk of watermark disease. Willow is mostly grown for fibrewood and clumpwood. Poplar is also grown for saw logs and veneer (Oosterbaan 2000). In short rotation coppice (SRC) systems these trees are also grown for biomass production and as such they could also function as an intercrop in agroforestry systems (see 5.4). Traditionally willow also yields twigs for the floral industry, basketry making, dike and waterside stabilization, fencing and many other uses.

**Alnus glutinosa and A. rubra (Black alder and red alder)**

Traditionally black alder was widely cultivated in the Netherlands for its fast growth, possibility to strive in wet conditions and its potential to fix atmospheric nitrogen and hence act as a natural fertilizer. Trees were usually planted along ditches as multifunctional riparian buffers, providing also timber, firewood and nitrogen fertilizer. The ancient system of narrow plots bordered with ditches and alder coppice are now seen as a cultural heritage and maintained through rules and subsidies (see Chapter 6).

Although black alder is traditionally regularly coppiced, Oosterbaan (pers.comm. 2004, Alterra Wageningen) indicates that standards of alder (20-50 years) can provide valuable timber. Since standards of alder are not frequently offered on the commercial wood market, demands seem higher than the offer. This may offer good opportunities for agroforestry, especially where traditional aldercoppice already exist and the traditional coppice-
management only has to be adjusted to also maintain standards for log production (Boer en Oosterbaan 2004)(Paragraph 6.1).
The same counts for the American red alder, which in an important lumber tree in N-America. It may be even more valuable than black alder, since it makes a good imitation mahogany and is used for cheap furniture etc. (PFAF 2004).
Alders grow well in wet poor or rich sands, sandy loams and light clays with a groundwater level lower than 20 cm in summer.

Other trees in short rotations
Garrett and McGraw (2000) note that the number of potential species for use in agroforestry systems are increased due to recent technological advancements in the use of juvenile soft hardwoods in making construction materials. As for poplar, the rapid juvenile growth of maple (Acer spp.) and birch (Betula spp.), yields high volumes per hectare on the short term, useful for soft-hardwood chips for the oriented strand board (OSB) industry as well as the pulp and paper industry.

4.2.2 Mid-term rotation species
Mid-term rotation species are trees that need a mid-term investment of 30 to 50 years to produce valuable wood for timber or veneer. Common forestry species as ash (Fraxinus excelsior) and maple (Acer spp.) (Section 4.3.1) may be very good options for their high quality wood and relative fast growth. According to Dupraz and Newman (1997) excellent clones of ash and maple have been selected for inclusion in silvoarable systems, but propagation techniques are not yet operative. Also robinia (Robinia pseudoacacia) and wild cherry (Prunus avium)( Section 4.3.1) are good wood producers on a mid-term.

4.3 Multipurpose trees
In the context of this report, a multipurpose tree is defined as a tree that has an economic value and that in addition to timber, provides directly marketable products on the short term.

4.3.1 Upper storey trees

Juglans spp. (Walnut)
In temperate agroforestry the common walnut (Juglans regia), the American black walnut (J. nigra) and the various modern cultivars of J. nigra x regia are commonly applied. The database of Plants For A Future (PFAF 2004) however, also mentions other Juglans spp. which may have good qualities for agroforestry, such as J. ailanthifolia (Japanese walnut).

J. nigra originates from the eastern half of the USA and has been the most valuable timber in North America. Much of the intercropping research and establishment in the USA has focused on black walnut. Its high timber value, aesthetic qualities, capacity for nut production, rapid growth, adaptability to management and certain foliage and root system characteristics makes black walnut an ideal agroforestry species (Williams et al. 1997). Black walnut is one of the last to break dormancy in the spring and one of the first to defoliate in the fall. This means more direct sunlight for intercrops and reduced competition for moisture, which is frequently in short supply in late summer (Williams et al. 1997). Even with full foliage (i.e. in summer), black walnut produces a rather light shade admitting slightly less than 50% of full sunlight, which is sufficient for most temperate-zone forage legumes and cool-season grasses which require about one-third full sunlight. Furthermore black walnut has a relatively
deep rooting system, leaving a shallow zone near the soil surface for development of companion root systems of intercrops (Williams et al. 1997). The dormant plant is very cold hardy, but the young growth in spring, however, can be damaged by late frosts (PFAF 2004). PFAF (2004) indicates black walnut does not fruit very freely in Britain. The tree is mainly cultivated for its wood and to a lesser extent for its fruits.

*J. regia*, the common or English walnut, originates from Europe and Asia and produces both high quality wood and edible fruits. Recently it is gaining more and more interest in Western Europe as wood producer for afforestation on arable lands and for agroforestry (SAFE 2004, Oosterbaan 2004, van den Burg 1998). *J. regia* grows more slowly than *J. nigra* and needs up to 15 years to come into bearing. The dormant plant is very cold tolerant, tolerating temperatures down to about -27°C without serious damage, but the young spring growth is rather tender and can be damaged by late frosts (PFAF 2004). In the last decades, hardy clones (often hybrids of *Juglans nigra x regia*) are developed that combine both quality wood and quality nuts. These modern cultivars start fruit production after 3 years and they produce also well in The Netherlands (Oosterbaan en Valk 2000). For production of quality wood a rotation of 50 years can be considered as a minimum (Oosterbaan 2000). The foliage and root characteristics of *J. regia* are comparable with those of *J. nigra*.

*J. ailanthifolia*, the Japanese walnut, is cultivated for its edible seed in Japan. It has the potential for producing very superior nuts, especially if hybridized with *J. cinerea* (the white walnut or butternut) from North America. Trees can come into bearing within 3-4 years from seed (SAFE 2004). This is the hardiest member of the genus and also resistant to the attacks of most insects. The young growth in spring, however, can be damaged by late frosts. Japanese walnut requires a deep well-drained loam, slightly alkaline soil (PFAF 2004) and a sunny position sheltered from strong winds. Other characteristics are comparable to those of *J. regia* and *J. nigra*.

Many combinations of intercrops with walnut have been tested, in experiments. Examples are cereals, maize, sorghum, soybean, rapeseed, canola, sunflowers, tobacco, aromatics, small-fruit, fruit trees, vineyards, alfalfa and grass (Nair 1993, Dupraz and Newman 1997). Research indicates that grasses grow well in walnut shade and are ideal for replacing row and/or specialty crops when shade reduces their yields (Williams et al. 1997, Oosterbaan et al. 2001). It can be expected that grass production under walnut will be little reduced in the first 10 years of establishment and will still be possible when tree crowns are closed (Oosterbaan et al. 2001). Silvopastoral experiments in the sandy Achterhoek region in the Netherlands show that at least during the first three years walnut has a very slow growth in height and diameter compared to chestnut and cherry. After three years the average crown cover of the walnuts was only a third of that of cherry (Oosterbaan et al. 2004). This suggests that walnuts will be less competitive for light, at least during the establishment phase, compared to cherry and chestnut.

Some investigations indicate that intercrops may suffer from the allelopathic effects of walnuts through the toxic substance juglone, while others do not (Oosterbaan et al. 2001). Juglone is formed out of a chemical which is dissolved out of the leaves, roots and twigs when it rains and is washed down to the ground below. Concentrations of juglone in the soil varies over the season (high in spring and autumn, low in summer)(Oosterbaan et al. 2001). Walnuts are said to inhibit the growth of many plant species, amongst others of maize, soybean and potatoes (PFAF 2004, Oosterbaan et al. 2001). Oosterbaan et al. (2001) mention an intercropping experiment in which the 62 % yield-reduction of maize was mainly attributed to the allelopathic effect of the trees.

On the other hand, in the French province Dauphiné walnut intercropping is traditionally practiced with a variety of crops, often cereals and maize (Dupraz and Newman 1997). In a French agroforestry experiment with cereals and oilseed rape no yield reduction was found during the first 8 years of tree establishment. Also in other experiments juglone seemed to
have little or no harmful effects on cereals (Mayus pers.comm. 2004, Crop and Weed Ecology Group, Wageningen). Moreover walnuts may decrease the production and biodiversity of weeds (Oosterbaan et al. 2001) and inhibit the establishment of undesirable forage species, thus reducing competition and allowing other more desirable species to grow uninhibited (Garrett and McGraw 2000).

In sum, more research is required to get a better understanding of the sensitivity of intercrop species to juglone and to make recommendations on the choice of companion crops, as allelopathic effects may have significant bearings on the total productivity of an agroforestry system. Nevertheless, the fact that walnut is one of the major species used in modern temperate agroforestry systems and intercropped with many species, may indicate that the positive effects of walnuts on the total system output may outweigh the negative allelopathic effects on the intercrop.

According to Williams (1997) a row spacing of 12.5 m is ideal for walnut production. Studies in Missouri have shown that black walnut planted on a good site will shade 12.5 m alleys within a 10-year period. If light-demanding crops are to be grown on such a site, row spacing must be increased to accommodate their needs. In contrast, a closer spacing and later thinning are required for shade-demanding intercrops such as ginseng. Within the rows the spacing can be shorter to provide enough surplus trees from which the best nut producers can be selected. For nut and wood production the trees should be thinned to approximately the most valuable 75 trees/ha within the first 25-30 years (Williams et al. 1997).

In France research is being done on cultivation on 4 m distances within the row, whereby the tree form is a vertical axis with horizontal side-branches. When the trees are fully grown, they are pruned with an inclined mowing bar, alternating the side of pruning year by year (Wertheim 1995).

Walnuts grow best on well drained sites and the soil should be fertile, calcium rich and allowing deep root growth. Ideal are (sandy) loam grounds (PFAF 2004, CRB 2002, van den Burg 1998). Unsuitable are poor sand grounds, heavy soils, shallow soils developed on calcareous layers (very rare in the Netherlands), peaty soils and very wet grounds. Van den Burg (1998) suggests that high soil fertility is not demanded for wood production, but rather for nut production. The hybrids of *Juglans nigra x regia* are usually less demanding on their growth place then their parents. For more specific information on growth places referred is to van den Burg (1998).

Various Dutch nurseries have selected and bred high quality (nut and wood) varieties fitted for the Dutch environment. At the experimental station for fruit growth in Wilhelminadorp various Walnut varieties were tested from 1974 onwards and the cultivars Broadview, Soleze, nr 139, Parisienne and Buccaneer appeared to give highest production. At 200 trees/ha (7 x 7 m), Broadview yielded just above 4 tons of nuts and Soleze between 3 and 4 tons of nuts as average over a three year period, making these the only profitable races considering prices in 1995 of € 2.25 – 2.70/kg nuts (Wertheim 1995).

Oosterbaan en Valk (2000) expect that walnut will start nut production after 3 years and at age 20 the trees will reach their full production of 18 kg/tree. They assume a yield of 0.5 m³ of valuable wood per tree after 40 years and have estimated the average net annual profits of a 1 ha plot of 100 or 25 trees/ha with grass and cows will be € 446 and € 595 respectively, or € 563 and € 622 respectively if the planting of the trees is subsidised. This calculation assumes an interest rates of 2 % and includes the removal of the stumps at year 40. In comparison: grass and cows only annually yields € 216 or € 523 with management subsidies.

Various machines have been developed for the harvesting of walnuts. In large plantings the trees are shaken mechanically, the nuts blown or harrowed together (after removing branches and smoothing the surface) and finally picked or sucked up mechanically before
cleaning. Hand machines are available for smaller plantings. They appear to work best on a grass surface (Oosterbaan et al. 2004). The mechanical picking of nuts means a severe limitation on the intercrop possibilities. In regions of France, where walnut and maize are commonly intercropped, the intercrop is either abandoned or reduced to a narrow strip as soon as the fruit-production becomes important (after 5-7 years) (Mayus pers.comm. 2004, Crop and Weed Ecology Group, Wageningen).

According to Nair (1993), various economic analyses have demonstrated that growing walnut solely as a timber crop is not economically viable, but that the addition of nut production and intercropping generally provides a positive benefit/cost ratio. In Southern France, results of a 9 year old silvoarable experiment of walnut (200 stems/ha) and durum wheat, showed a significant better growth of walnut in agroforestry than in the forest control. However, it was not clear if the increased growth was due to facilitation processes or due to a difference in water table and soil management (SAFE 2004). Within the SAFE project, economic analysis for walnut agroforestry systems is currently in work, since walnut next to poplar were seen to have a good potential in the Netherlands (SAFE 2003).

**Castanea sativa** (Sweet chestnut)
The sweet chestnut originates from the Mediterranean region, but is grown in North-Western Europe since Roman Times (van den Burg 1998). It produces a good quality wood and valuable fruits.

The requirements of the chestnut are comparable to those of (summer)oak (CRB 2002), but it is more shade-tolerant. It requires a deep, light and aerated soil. Oosterbaan (2000) advises rich sand grounds, sandy clay or light clay with a groundwater level deeper than 80 cm in summer. It prefers acidic grounds with as little CaCO3 as possible. Demands regarding soil fertility are not high, but it grows bad on very unfertile soils, calcareous soils, badly drained soils and heavy clays. Once established, chestnut is usually very drought tolerant (PFAF 2004, Ciesla 2002, van den Burg 1998). The tree prefers warm summers and mild winters and is sensitive to early and late frost.

Ciesla (2002) suggest that the preference of chestnuts for lighter soil provides an opportunity to utilize land that is marginally productive. Nevertheless, chestnut trees on heavier (clay) soils have been noted to perform in outstanding fashion if the drainage patterns prevent standing water or soil saturation for extended periods. Furthermore chestnut is deep rooting and as such may be compatible with intercrops. More specific information on growth requirements are given by van den Berg (1998).

In a silvopastoral experiment on sandy soils in the Achterhoek, the Netherlands, chestnut growth during the years of establishment was high compared to walnut, but lower than that of cherry (Oosterbaan et al. 2004). Three years after planting stem-diameter and crown cover were much higher than that of walnut and almost as high as for cherry. In term of light-competition, chestnut will probably take an intermediate position in between walnut and cherry.

For production of quality wood a rotation of 40 years can be considered as a minimum (Oosterbaan 2000). Oosterbaan en Valk (2000) assume that chestnut will produce 2 kg of fruit at age 5, 10 kg at age 10 and 20 kg at age 20. They expect a wood-yield of 1.0 m³ per tree after 40 years and have estimated the average net annual profits of a 1 ha plot of chestnuts (100 trees/ha) with grass and cows will be € 514 over 40 years if the planting of the trees is subsidized. This is including the removal of the stumps at year 40 and a 2 % interest rate. In comparison: grass and cows only annually yields € 216 or € 523 with management subsidies.

Harvesting techniques of the nuts are comparable to those of walnut. The nut collection in silvoarable fields will be accompanied with the same complications as described above for
walnut. Hence, as soon as the trees become productive and mechanical picking is required, intercrop possibilities are limited.

**Prunus avium** (Wild cherry)
The wild cherry or sweet cherry occurs naturally in the whole of Europe except the north and north-east. It traditionally produces both a highly valued wood and good fruit. For purposes of wood-production however, also fast growing clones are developed that produce no or only very small fruits (CRB 2002, Dupraz and Newman 1997).

Wild cherry grows well on most soils if not too poor and not too wet. Oosterbaan (2000) recommends rich sand, sandy clay, light clay and heavy clay with a groundwater level deeper than 50 cm in summer. For an optimum tree development, deep and rich soils are preferred, that are moist, but not wet. It thrives in a loamy soil. For fruit production heavy clays and badly drained soils are unsuitable. A bit of calcium is appreciated (PFAF 2004, van den Berg 1998). Although cherry prefers sunny and warm places, it is little sensitive to late frost and susceptible to wind damage. Specific information about the required growth conditions are summarized by Van den Berg (1998).

Wild cherry showed the fastest growth in the agroforestry experiment in the Achterhoek (Oosterbaan et al. 2004). This suggest that cherry might be rather competitive for light and that the intercropping period for light-demanding crops may be shorter than with chestnut and walnut. On the other hand, cherry would cast a light shade (PFAF 2004). PFAF (2004) mentions that most members of this genus are shallow-rooted and hence likely to compete with the crop for belowground resources. Wild cherry would be a bad companion for potatoes, making them more susceptible to potato blight and is also known to suppress the growth of wheat. Moreover, it grows badly with plum trees, its roots giving out an antagonistic secretion (PFAF 2004).

A tree life cycle of a minimum of 40 years is needed to obtain a quality timber (Oosterbaan 2000). At a density of 100 trees/ha, Oosterbaan en Valk (2000) expect that cherry will start producing cherries after 5 years, will produce fruit only once every five years and at age 10 will produce 5 tons of cherries/ha. They assume a wood-yield of 1.5 m³ per tree after 40 years and have estimated the average net annual profits of a 1 ha plot of cherries (100 trees/ha) with grass and cows will be € 480 over 40 years if the planting of the trees is subsidized. This is including the removal of the stumps at year 40 and an assumed interest rate of 2 %. In comparison: grass and cows only annually yields € 216 or € 523 with management subsidies. It has to be noted however that cherries also need protection from birds, which is not included in the calculation.

**Prunus domestica** (Plum)
Plum naturally occurs from Europe to Western Asia. Its requirements and most characteristics are similar to those of wild cherry (PFAF 2004). Little research is done on its applicability for agroforestry, but its slow growth may make it a better companion tree than cherry.

**Malus domestica** (Apple) and **Pyrus communis sativa** (Pear)
Nowadays, in the Netherlands, most commercial fruit-orchards consist of dwarf varieties planted in dense rows with narrow strips of bare ground or grass in between. In principle this area could also be effectively used for the cultivation of winter/spring vegetables. The traditional high-stem fruit trees are planted at wider spacing. For centuries it was very common to let sheep or other livestock graze under the trees in high-stem orchards. With the introduction of dwarf varieties though, most high-stem trees were replaced and also the silvopastoral combination got rare (Gijsbers 1994).
Apple and pear trees can grow on most soils if well drained and moist, but prefer fertile soils for optimum development. Pears are quite tolerant towards excessive moisture and drought, if well established (PFAF 2004). They have a deep rooting system (CRB 2002), which may make them a good tree for agroforestry purposes.

The disadvantage of dwarf fruit trees is that they do not produce high quality wood logs and as such the income should come mainly from the fruit. In contrast, high-stem fruit trees can also produce valuable stems of excellent quality wood. Current subsidies on high-stem trees (Chapter 6) may compensate for the lower production and high labour costs and make high stemmed agroforestry fruit gardens viable again.

**Robinia pseudoacacia** (Black locust)
Black locust originates in the Appalachian mountains in the USA and has been grown in Europe since the 17th century. It is widely grown in Eastern Europe (Hungary) for its high quality wood. Special cultivars are also grown for honey-production. In the Netherlands it is usually grown as a park and lawn tree and it is only recently that it receives attention for commercial production. Apart from its pole wood and high quality saw wood, it bears rich fragrant flowers which are very suitable for bee-production and may also be valuable as a decorative floral. Hence this can lead to early benefits. Additionally it fixes atmospheric nitrogen, which may become available to the intercrop through its roots and leaf mulch.

Robinia is quite tolerant regarding soil quality, but wet, cold soils are unsuitable. It is resistant to drought and grows reasonably on dry unfertile grounds, if they are deep enough (van den Burg 1998). Oosterbaan (2000) recommends poor sands, dry rich sands, sandy clay or light clay, with a groundwater level deeper than 80 cm in summer. Robinia has a reasonable pH tolerance. The availability of P may be important in relation to the atmospheric N-fixation. Opinions on its susceptibility to late and early frost are divided. The temperature in the vegetative period is very important though, which may mean that the temperature in the NE of the Netherlands may be limiting to growth (van den Burg 1998). Robinia has a rapid initial growth, which gets less at a later stage.

Robinia comes into leaf quite late which could make it compatible with intercrops. On the other hand the root system is often found to be rather superficial and extensive, making it compete with the intercrop. Some authors claim though, that the root system can go quite deep, depending on the permeability of the soil and the groundwater level. Root architecture may also depend on the variety of Robinia (van den Burg 1998), which makes it important to make a good choice of cultivars for inclusion in agroforestry systems. CRB (2002) makes notice that Robinia forms a superficial rooting system on rich soils and a deeper rooting system on poorer soils.

**Acer spp.** (Maples)
Acer-species are fast-growing trees, which produce valuable wood for timber, vineer and fibre. Maple-species are easy to cultivate. They prefer a good moist well-drained soil but thrive in any soil. Some can even grow well on heavy clay and nutritionally poor soils (PFAF 2004). For the Dutch sycamore, Acer pseudoplatanus, Oosterbaan (2000) recomends rich sands, sandy loam and light clay with a groundwater-level deeper than 50 cm in summer. Maples tolerate some shade and are very wind-resistant, tolerating maritime exposure though it is often wind and salt pruned in very exposed areas (PFAF 2004, CRB 2002). PFAF (2004) makes notice that maples are bad companion plants, inhibiting the growth of nearby plants. This may limit their application in agroforestry. In North-America however, maples are often cultivated in forest-farming systems combined with ginseng or other medicinal plants.
(Hill and Buck 2000). Also other sources recommend maples for inclusion in agroforestry systems (Garrett and McGraw 2000, Dupraz and Newman 1997). Especially interesting for agroforestry-application is the North-American sugar maple (*Acer saccharum*) and its subspecies the big-tooth maple (*Acer saccharum grandidentatum*). Their wood is considered by many to be the most valuable hardwood tree in N. America (PFAF 2004). The sap of these trees is traditionally tapped and processed into maple syrup, which is used as a sweetener on many foods. It is used extensively in North America. In the Netherlands the market is only small but may be developed. The maple-syrup available in the Netherlands is now imported, but may be produced here as well. PFAF (2004) however, mentions that the best sap production comes from cold-winter areas with continental climates. Other maples, including the Dutch sycamore, also produce sugar-rich sap, but usually not in economic quantities (PFAF 2004).

**4.3.2 Lower storey trees**

*Corylus* spp. (Hazelnuts)
The Dutch hazelnut (*Corylus avellana*) is a large shrub and only gets 2-5 m high. It grows on calcium and humus rich soils in moist forests. For optimum production, the soil should be well drained, drought resistant and with a pH between 4 and 7 (Kwanten 2004).
The Turkish hazel or tree hazel (*C. colurna*) is a tree up to 15 m high and is planted in the Netherlands as a park- and lane tree (Janson 1989). The Turkish hazel is resistant to drought. If the soil permits it, they will form a deep rooting system. Drought tolerance and deep rooting pattern are good properties for agroforestry systems, but there is no experience with respect to commercial nut production of the Turkish hazel in the Netherlands. The same counts for *C. maxima*, the filbert, a deciduous shrub from Southern Europe growing to 6 by 5 m. Both *C. colurna* and *C. maxima* have often been hybridized with *C. avellana* in breeding programs in order to develop superior fruiting cultivars (PFAF 2004). Hazels can grow in semi-shade (light woodland) or no shade (PFAF 2004) and may thus be used as a secondary storey of agroforestry systems, growing under taller trees. Hazels succeed in most soils, but generally produces more nuts when grown on soils of moderate fertility (PFAF 2004).

Although the Dutch hazel is an endemic species, commercial cultivation is still very limited. Foreign cultivars have been evaluated in experiments and are grown on a small scale, but sub-optimal yields and quality, and susceptibility to disease have prevented a further increase in acreage. It is only recently that, through selection and breeding of Dutch wild hazelnuts, new cultivars were developed with excellent yield potentials and other good quality characteristics (size, shape, taste, pellicle removal) (Schepers and Kwanten, in progress).

Hazels are generally not susceptible to serious pests and diseases and grow on most soils, if not constantly wet. This makes them especially suitable for organic cultivation.

Nowadays there is a whole range of Dutch and foreign hazel cultivars available. Due to genetic differences, the productivity of the various cultivars is very variable. Kwanten (2004) mentions that good cultivars have an early production and yield about 4 kg of dry nuts per shrub in year 4 up to 12 kg from year 10. Meer van Oeveren (1997) says hazelnuts reach full production after eight years and 2,5 kg per tree is an average annual harvest, but yields may reach 8 or 9 kg, depending on race and year.

Alternate bearing (not every year is a good seed year) often occur and are often related to weather. To prevent this as much as possible, it is recommended to arrange for good pruning and sufficient moisture and to choose for less susceptible varieties. With a good crop plan the average harvest over the first 15 years is 3500-4500 kg of dry (still hulled) nuts per ha of nut-orchard (Kwanten 2004). In Groningen still many varieties and under-stems are tested...
and selected for the Dutch environment. It is essential to include certain races for good pollination. Pollinators should make up about 20% of the planting to get good yields.

Research at the experimental station for fruit culture in Wilhelminadorp in the South of the Netherlands have indicated the potential to grow Dutch hazelnuts on a big scale. Nowadays 90% of the hazelnuts are imported from Turkey, but Dutch varieties can compete in quality and could take away the yearly insecurity of the Turkish production. Research suggest that the cultivation of hazelnuts can financially compete with that of sugar beets (Dorresteijn 1996).

Fully grown trees of the best producing French cultivars yield 4500 kg/ha dry nuts including the hull, or 2000-2500 kg of dry dehulled nuts. These are harvested by up to 4.5 m wide ‘sweeping machines’ and are artificially dried. With these methods French hazelnut production has risen considerably since the 80’s, both through improved cultivars and new plantings. In the Netherlands the harvest is usually coordinated by ‘De Notenunie’ and boarded out to a contractor.

Meer van Oeveren (1997) mentions also an example of an innovative Dutch farmer who rebuilt a liquid manure tank into a hazelnut picking machine.

Good experiences were noted on the organic intercropping of hazel, walnut and the woody shrub sea buckthorn (Hippophaë rhamnoides, see Section 4.4.2) since 1996/1997 on a sandy soil in the Noordoostpolder in the province of Flevoland (Schepers and Kwanten, draft in progress). Rows were alternatively planted with Sea Buckthorn and nuts (walnuts and hazelnuts) The distance between the rows was 3.5 m. In the rows the sea buckthorn plants were planted 1.2 m apart. In the other rows, hazelnuts and walnuts were planted alternatively with a distance of 3.5 m.

Berries of the sea buckthorn are harvested since 1999, but the plants have to be pruned dramatically to prevent competition with the hazels and walnuts. The sea buckthorn plants will have to be completely removed in the near future. The hazelnuts started to produce in 2002. In 2003 the average yield of three cultivars and the pollinators was a little over 1 kg dried nuts/plant. The large size of the nuts, the high internal quality and the organic certification make the nuts into a very attractive product.

### 4.4 ‘Specialty trees’ with potential for AF

The following section will give a selection of further trees, with potential for application in Dutch agroforestry. The selection comprises trees that show good performance and appear to be, or used to be of economic value in either the Netherlands or in other temperate countries. They comprise mainly fruit trees and some other trees producing marketable products on a short term. Most of these ‘specialty trees’ are not cultivated on a commercial scale in the Netherlands and consequently most of their products have not yet an established market in the Netherlands. This gives the innovative agroforester the opportunity to search and develop niche markets for their products. Market-research is recommended before applying such trees.

#### 4.4.1 Upper storey trees

**Gleditsia triacanthos** (Honeylocust)

Research suggest that the American native honeylocust (*Gleditsia triacanthos*) has great potential for agroforestry. Garrett and McGraw (2000) mention that *Gleditsia triacanthos* by nature has small, sparse foliage and a long period of leaf retention. The root system develops from a central taproot that can extend downward to 3-6 m permitting the tree to
absorb water and nutrients of great depths. Moreover, it usually has fewer lateral roots than many other potential agroforestry trees, which minimizes its competition with the companion crop. These characteristics make honeylocust interesting for inclusion in agroforestry systems. It succeeds on most soils, so long as they are well drained and can grow on nutritionally poor soils (PFAF 2004). PFAF (2004) makes notice that this species likes long hot summers and may thus not produce well in maritime climates. Further research may thus be necessary to confirm their value in the Dutch climate.

Research findings (Dupraz and Newman 1997) show the potential of *Gleditsia triacanthos* as a fodder tree for ruminants. The pods of selected varieties appeared attractive to sheep and to have good feeding value. Sheep fed only with Gleditsia pods gained 135 g/day, but combining pods and rough feed would probably have a higher retention time in the rumen and therefore allow even higher digestibility of the pods. A variety with soft seeds easily broken at ingestion or rumination would have a protein digestibility as high as 70 or 80 %, making Gleditsia pods a viable alternative to soybean seeds.

It is estimated that on a deep soil with high water resources, an orchard at 200 trees/ha may produce about 2 ton of pod dry matter at age 10 years (Dupraz and Newman 1997). Trees show an alternate bearing pattern and some varieties are in opposite phases, making a mixture of clones necessary to achieve sustained yields. More research is needed though to identify soft seed varieties of Gleditsia, to develop easy and cheap vegetative propagation techniques and to confirm productive data.

**Arbutus unedo** (*Strawberry tree*)
This tree from southern Europe has proven to grow and crop very well in temperate regions and produces edible fruits (PFAF 2004). The tree is very ornamental; it stays green year-round and in autumn and early winter its dense mass of greenery is mingled with a profusion of white flower clusters and red round fruits resembling small strawberries. The fruit remains on the tree for twelve months, not maturing until the autumn succeeding that in which the flower is produced (Botanical.com 2004). When fully ripe it falls from the tree and so it is advisable to grow the plant in short grass in order to cushion the fall of the fruit (PFAF 2004). This makes the trees most suitable in silvopastoral systems. Its beauty makes this tree especially attractive for recreational purposes. Dwarf varieties are also available. The plant prefers light (sandy) and medium (loamy) soils ranging from acid to alkaline, requires well-drained soil and can grow in heavy clay soil. It also grows in semi-shade and could thus also be used in the lower storey. The plant can tolerate strong winds and maritime exposure (PFAF 2004). Meredith (2002) notes it grows well on the British coast, but not in the colder parts of the country.

**Caragana arborescens** (*Siberian pea tree*)
This leguminous tree is said to have potential to become a staple food crop for its nutritious and wholesome seeds. Although the seed is rather small it is often very freely borne and is easily harvested. Furthermore it is a very ornamental plant and is noted to attract wildlife. The tree or shrub grows up to 6 m at a fast rate and can also be grown as a hedge. It grows well in most well-drained soils, preferring full sun and a light sandy dry or well-drained soil. It tolerates very alkaline soils, drought and even succeeds on marginal land (PFAF 2004). It has an extensive root system. This tough tree may especially be a good alternative for agroforestry systems on sites where other trees are hard to grow. *C. boisii* and *C. fruticosa* are closely related to this species and can probably be used similarly.
**Cydonia vulgaris** (Quince)
This is an up to 5 m. tall tree with fruits like hard yellow pears. The fruits are very fragrant and are commonly used to make jelly. Its is a good source of pectin. Quinces were once grown quite extensively in N-America and Europe, but pest problems limit their use today. Quinces prefer a fertile site in full sun. They should be planted in a protected environment because they respond poorly to rapid changes in temperature and exposure (Hart 1996).

**Juniperus communis** (Juniper)
The only native Dutch conifer is primarily grown for its berries, which have an essential oil of medicinal value. This is an easily grown plant, which succeeds in most soils so long as they are well drained, preferring a neutral or slightly alkaline soil. Grows well in heavy clays and poor soils and is tolerant to drought. It tolerates some shade, but grows best in sunny conditions (PFAF 2004). Being a native conifer, juniper could be a good option for semi natural agroforestry systems on soils, where other trees will not grow.

**Morus spp.** (Mulberry)
This tree used to be the “king of the tree crops”. *Morus rubra* originates from the USA, *M. nigra* and *M. alba* from Central Asia. It grows up to 6-15 m. After some years it gives good crops of luscious fruit like large raspberries, which can be eaten fresh or made into jam, jelly or wine (PFAF 2004). The fruits are soft and fall of the tree when ripe. They should be gathered by covering the ground and shaking the tree. Their softness and uneven ripening make them unattractive for large-scale cultivation, but it may well be a good tree for the development of specialty or regional products with added value. In China mulberry is traditionally cultivated in agroforestry systems (Huang 1998). They prefer deep open sandy soils and need moderate moisture, but even do surprisingly well on a wide range of adverse soil conditions (Eames-Sheavly 2001). They perform best in full sun, but will tolerate part shade. The root system is superficial and widely spread. Huese (2000) suggests that the mulberry could be a good natural trellis for grapevines in forest gardens.

**Amelanchier spp.** (Juneberries)
More than 25 species of juneberries are native to N-America. They grow up to 8 m tall and produce small juicy fruits that are commonly used in pies and preserves. They prefer full sun and acidic well drained soil, but they will tolerate shade and a wide range of soils (Eames-Sheavly 2001).

**Cornus spp.** (Dogwood)
There are various species in these genus that produce wonderful fruits. Some of the most promising species are described below and in Section 5.3.2.

*C. kousa* (*chinensis*), the Japanese dogwood grows up to 10 m and is a very ornamental tree. Its fruits are the size of very large strawberries and have a succulent flesh with an exquisite flavor. The skin is fairly soft and can be eaten with the fruit, but it does have a decidedly bitter flavor (Meredith 2002). It grows in most soils, but prefers a rich well-drained loamy soil and a position that is at least partially sunny (PFAF 2004).
4.4.2 Lower storey trees

**Malus pumila** (Crabapple)
Crabapples are short, neat trees, which are very suitable for the low tree layer of a forest garden (Hart 1996). They are first class pollinators of ordinary apples. Since they can give good yields and some of them are highly palatable, this may be a good candidate to produce for the niche market. It is an easily grown plant, which succeeds in most fertile soils, preferring a moisture retentive well-drained loamy soil. It also grows well in heavy clay soils (PFAF 2004).

**Crataegus spp.** (Hawthorns)
The hawthorns are adaptable small trees and shrubs, of which the fruits are commonly eaten in many countries. They have little demands on behalf of the soils, but optimum growth is attained on nutrient- and calcium rich, loamy soils. Crataegus roots very superficially, making it vulnerable for heavy wind when grown as a tree. Grown as shrubs they are little susceptible. This rooting pattern may also imply a certain limitation to their combination with shallow rooting intercrops. It grows both in sun and light shade and as such would be well suited as a layer under higher trees (Janson 1989). The Dutch hawthorn (**Crataegus oxyacantha**) only produces small inedible fruits, but many foreign Crataegus species form larger edible fruits. One of the best is the Mediterranean Azerole (**Crataegus azerolus**), a small tree with comparatively large yellow or pinkish fruits shaped like miniature apples (Hart 1996). For extensive info on various **Crataegus** species, see PFAF (2004).

**Elaeagnus spp.**
This is a genus of wind-hardy silvery shrubs or small trees related to the olives. **E. angustifolia**, **E. parviflora** and **E. multiflora** all have edible fruits. **E. umbellata** forms small red or orange berries which taste like red currants. Hart (1996) claims this species is shade-tolerant and additionally fixes nitrogen, making it very interesting for inclusion in agroforestry systems. PFAF (2004) however note that **Elaeagnus** species cannot grow in the shade. **Elaeagnus** species grow well in most soils that are well-drained. They prefer a soil that is only moderately fertile, succeeding in very poor soils and in dry soils. They are very hardy and very tolerant to maritime exposure.

**Aronia spp.** (Chokeberries)
Chokeberries originate from the eatern half of North America. **Aronia**'s are small trees growing up to 4 m. They grow in most soils, if well drained and can grow in the sun or in half-shade (PFAF 2004). The purple fruited chokeberry (**Aronia x prunifolia**) is being cultivated in the Northern Netherlands and juice, jam and syrup are marketed as regional products (waddenproducten 2004).

**Hippophae spp.** (Buckthorn)
This genus includes some very usefull species. Two species with major potential for agroforestry are described below.

Sea buckthorn (**Hippophae rhamnoides**) is a shrub species, which grows up to 6m and is indigenous to the Netherlands. It forms small berries rich in provitamin A and vitamin C, which are said to give strength and reinforcement. They can be readily eaten, but are mostly
made into juices, jams, syrup, liquor or as additives to ice-cream and milkshakes. Branches with the orange berries are favorite in ornamental flower pieces. Fruits, leaves and branches are used to make medicinal oils. This crop is already cultivated on a commercial scale and marketed as a regional product in the coastal region of the North of Holland (waddenproducten 2004). It grows on most soils so long as they are not too dry (PFAF 2004), but best on open and deep sands or loams. It grows well by water and in fairly wet soils and is resistant to maritime exposure. They cannot grow in shade. They form a strong taproot and fix atmospheric nitrogen, which makes them very suitable for agroforestry systems. A further advantage is that the market for products of sea buckthorn is already partly developed.

Hippophae salicifolia, the willow-leaved sea buckthorn, is a vigorous large deciduous shrub that suckers freely and so is not suitable for places where space is limited. It has similar demands and qualities as Hippophae rhamnoides. Recent research has shown that this plant produces the most nutritious fruit yet discovered in temperate zones, regular use can prevent cancer whilst large quantities have been shown to reverse the growth of cancer tumors (Meredith 2002).

Cornus mas (Cornelian cherry)
This is a small, 5-6 m tall tree, that produces olive-sized fruit that can be used in jellies, tarts and sweetmeats. It produces yellow flowers in midwinter and is particularly attractive at this time.
It grows in full sun and partial shade and can be planted in shady areas under big trees. It prefers fertile, well drained soils, but tolerates a wide range of soils. It is usually pest-free (Eames-Sheavly 2001).

Woody decorative florals
Many woody plant species that have a colorful or unusual shaped stem, bud, flower, leaf or fruit can be used for decorative floral product. Examples are: cultivars of yellow- and redstemmed dogwood (Cornus spp.), many kinds of willows (especially curly and pussy willow, Salix spp.), red birch (Betula lenta), flowering branches of forsythia (Forsythia spp.), witchhazel (Hamamelis spp.). Also flowering branches of previously mentioned species, such as apple, plum, cherry, and fruiting branches of Sea buckthorn (Hippophae rhamnoides), are valuable for this purpose. Cuttings from coniferous trees have potential as floral greens.

Ornamental branches may be obtained when pruning tall trees. However, as good opportunities exist to obtain substantial returns by producing and marketing such decorative woody stems (e.g. Hill and Buck 2000), it should also be considered to plant shrubs and trees especially for this purpose, e.g. planted in the tree rows under taller trees or as a coppice intercrop.

4.5 Conclusions

There is a large variety of tree species with potential for temperate agroforestry. In this chapter it was tried to give an impression of the range of possible species for application in Dutch agroforestry systems. It was not tried here to identify the “best species”, since the agroforester’s choice for a certain tree species is dependent on a many factors, such as the site-characteristics, intercrop species, farm-management and -objectives (Chapter 8).
A survey among Dutch farmers' and estate owners' about their attitude towards agroforestry revealed that a preference is given to trees that provide income on the short term, especially in the form of fruits/nuts (Chapter 7). It must not be forgotten however, that also fruit trees will take 5-10 years to yield fruits. The well known species walnut, hazel and chestnut provide marketable products without difficulty and are suitable for application on highly mechanized farms. Other species may be more labour intensive, but yield specialty products and may thus suit best for small scale farms. Fast growing trees as poplar may, in favorable conditions, produce marketable wood in less then 25 years.

However, it must be understood that landowners with affection or trust in (agro)forestry, may also be interested in growing trees that in the end will give good returns, but need a mid-term investment up to 40/50 years. Landowners with the prime aim of producing quality wood on a mid-term, have the choice of a great variety of trees species, some of which, such as poplar, cherry, maple and ash, show great potential for agroforestry applications. Also species as Sorbus domestica, S. torminalis and Pyrus communis seem promising for wood production in agroforestry systems, but have not yet been researched for top-grade planting material (Dupraz and Newman 1997). For extensive information on the current recommended varieties and provenances of trees, referred is to the 7th list of tree races (CRB 2002).

According to Kuipers (pers. comm. 2003, Stichting Bos en Hout, Wageningen), the most interesting timber tree species for agroforestry in the Netherlands are poplar, walnut and wild cherry. Most information on silvoarable agroforestry in Europe concerns the use of deciduous trees, mainly because the emphasis is placed on light demanding row crops as intercrop species. However for silvopastoral systems and silvoarable systems with alternative intercrops, such as shade-tolerant specialty crops, forages and horticultural species, conifers may also be suitable.
5. Intercrops for temperate agroforestry systems, in particular the Netherlands

5.1 Introduction

An agroforestry system will comprise at least one layer of intercrops, e.g. a layer of pasture or cereals in silvopastoral or silvoarable systems respectively, but may also consist of two or more layers, up to seven layers of intercrops in complex forest gardening systems (Section 2.4.3). Choosing intercrop species, one can use comparable criteria as for the tree species:

1. the intercrop is economically profitable in the relatively short term
2. the intercrop is adapted to the local circumstances
3. the intercrop is compatible with a tree component (preferably with positive interaction)

As explained in Section 3.3.1, a major constraint for temperate agroforestry systems is the amount of radiation available for the intercrop. In tropical regions, the strong light conditions allow even under storey layers in multi-strata systems to receive substantial light, whereas in temperate regions this is not the case (Hill and Buck 2000). Therefore, in the Netherlands, the agroforestry intercrop must be chosen very carefully considering light conditions, which depend on tree species, tree size and system design. During the first 3 to 7 years of an agroforestry system the tree shade effect is negligible (Section 5.2). In a later stage however, decreasing light conditions may constrain the growth and ripening of light demanding intercrops. To maintain a profitable agroforestry system and to optimize the LER (land equivalent ratio), chosen could be for tree thinning, tree pruning, increasing the tree-crop distance or choosing for shade-tolerant or shade-demanding intercrops. There are plenty of crops which tolerate shady conditions, but many are not well known.

The possible intercrops for inclusion in agroforestry systems can be roughly divided into four groups: conventional "bulk production" food- and forage crops (cereals, maize, potatoes, beets, grass and vegetables), smallfruit, specialty crops and non food crops for fiber and biomass production. In the following chapter, these crop groups will be described including their qualities and growth requirements, which indicate their potential and their possible role in agroforestry systems. Where possible, an analysis will be made of the experiences regarding the inclusion of the various groups and/or species in agroforestry systems.

5.2 Conventional agricultural crops

5.2.1 Cereals, maize, potatoes, sugarbeets and fodderbeets

When we consider silvoarable agroforestry as wide spaced tree rows on an arable field and if the distance between tree trunk and crop field is 0.5 to 1 meter, it can be expected that there will be little or no competition-effects between the trees and intercrop for the first years after tree planting and in principle it should thus be possible to cultivate almost any conventional crop as intercrop during the initial years of tree establishment. Data available so far indicate that little if any yield reduction of crops was observed during the first 5 to 7 years in silvoarable systems with slow growing high quality hardwoods, such as walnut or wild cherry (Garrett and McGraw 2000, Dupraz and Newman 1997, Nair 1993). This is particularly true for winter crops (Mayus pers. comm. 2004, Crop and Weed Ecology Group, Wageningen). In
case of summer crops, the development of tree canopy and crop growth are more synchronous and thus yield reduction should be more important. Moreover, with increasing tree density, yield reductions due to shade and eventual below ground competition will occur earlier within the agroforestry life cycle. The latter is true also for trees with large and dense canopies as that of poplar. With poplar, the outcomes of various investigations varied considerably, possibly due to different tree densities. Newman (1994) found dramatic decreases in cereal yield at age five, but no significant yield decrease at the age of three in one experiment, while in another experiment no yield decreases of wheat was noticed at 6 years age (Newman 1994). Dupraz and Newman (1997) report about a silvoarable system practiced by a British company in the 1950’s. The alleys between the rows of poplar in this system were cropped successfully with cereals for 8 years and the last cereal was undersown with a grass-clover mixture.

In an experiment in the Netherlands (Edelenbosch 1994) little or no yield decrease was noticed for sugarbeets and maize in the first 2-3 years at 202 poplars/ha (4.5 x 11 m), while at age 4 the yield decrease was about 20 %, making for still a profitable intercrop. Poplars did show a decreased growth though: 10-15 % in dbh (diameter at breast height) and 4-5 % in height, equaling less than half a growth season. In another experiment (Swellengrebel 1990) with poplar at 3 x 3 m and an intercrop of fodderbeet, the loss of the non-cropped tree strips (28 % of the surface) was roughly compensated by clearly visible better growth of the beets bordering the tree-lines. This is probably primarily caused by the bigger growth-space of those beets, but maybe also by the shelter of the trees. Beets were intercropped for three years and no yield reduction was measured.

Garrett and McGraw (2000) and Nair (1993) give numerous examples of intercropping practices during the first years of tree establishment in orchards and plantations in many different temperate countries, for instance with corn, soybean, milo, wheat, barley, oat, potato and other tuber crops. Dupraz and Newman (1997) mention that in the French walnut production area of Dauphine 20 % of the walnut orchards are intercropped with conventional crops as maize, winter cereals (durum wheat, wheat, barley), sunflowers, canola (Brassica napus) and tobacco. 80 % of the orchards aged 10 years or less. They also mention that in Dauphine short intercrops are often preferred to maize, which allows better ventilation of the tree canopy and reduces the impact of diseases on the foliage. This may indicate that maize and other high and dense growing crops may not be ideal intercrops for walnut and maybe for other slow growing trees. They may well combine with fast growing species as poplar though, considering the good experiences with maize-poplar intercropping, at least in the first years of poplar establishment (Edelenbosch 1994, Dupraz and Newman 1997).

Research on modern temperate silvoarable agroforestry is still in an early phase. This and the fact that the agroforestry design, species and circumstances in agroforestry experiments with conventional crops are rather heterogeneous, makes it is difficult to make clear-cut statements on which crops are most suitable in later phases in the development of the agroforestry system, when competition effects will become stronger. As mentioned earlier, there are several investigations that have shown that cereals are still able to grow as an intercrop after 6-8 years. There are examples of 20-25 year old walnut orchards intercropped with soybean and cereals in France (SAFE 2004). These examples suggest that at least cereals will not quickly suffer from a little shade and may be maintained as an intercrop for quite a long period. Winter cereals have the particular advantage of being able to establish themselves when the trees are leafless and in rest, which means little above- and belowground competition.

The main advantage of cereals and maize over potatoes and beets is that they demand relatively few machinery runs (for weeding and spraying). As explained in Section 3.3.3, tree rows will often mean a lower efficiency with the machinery and more labor. Consequently potatoes and beets will cost even more labour and will decrease the net returns of these
crops in agroforestry. More machinery runs will increase the chance to damage stems and branches with the machinery and the harvesting of root crops will mean a higher chance of damaging tree roots. Additionally, potatoes and beets are often harvested with a car next to the harvesting equipment, which will mean the necessity of a clear strip next to the crop to allow for the car. This would mean a clear strip of about 3 m next to each tree-row, making the system very inefficient. However, with a combiner-harvester this problem does not exist. Potatoes are also known to produce much less under influence of tree plantings. Windbreaks however, are known to increase yields and sugar-production of sugarbeets due to the better microclimate (Boer en Oosterbaan 2004).

5.2.2 Vegetables
In general the same count for vegetables as for the crops mentioned above: intercropping practices of vegetables in the first years of orchard establishment indicate that no growth reduction are expected in the first up to ten years as long as the tree crowns are open enough to permit enough sunlight to reach the vegetables. Nair (1993) gives various examples of intercropping fruit orchards with vegetables and notes that in Washington State approximately 10 % of fruit orchards are intercropped with vegetables, mostly for home use.

The advantage over the crops mentioned above is that the open structure and the rooting pattern of certain vegetables may mean less competition for nutrient and water. Although common vegetables will not thrive in full shade, certain species are known to withstand some shade, for instance endive, beet-root, peas, runner- and faba-beans, radish, spinach, sprouts, rhubarb, lettuce, cabbages (PFAF 2004, faq van NL.tuinen 2003). In general leafy vegetables are supposed to be quite shade-tolerant and may even benefit from some shade.

Winter- and spring vegetables have the advantage of growing in the period when the trees show least competition for light, water and nutrients. Vegetables as kale, winter carrots, winter salads, and early cabbages, spinach and radish may thus have good potential for intercropping.

5.2.3 Pasture and forage

5.2.3.1 General
In temperate zones, grass is often considered as one of the most economic intercrops in aged agroforestry systems, where shade makes the cultivation of conventional crops uneconomic. Combinations of high-stem fruit trees with low densities per hectare intercropped with grass and grazed by livestock were once very common in the Netherlands, especially in the Betuwe between the rivers Maas en Waal and in Zuid-Limburg. The improved efficiency in fruit-growing through the introduction of short-stem cultivars, which are planted at high densities, has resulted in virtual disappearance of highstem orchards (Gijsbers 1994). In the Netherlands, in 1945 several ten thousands of hectares of high-stem orchards existed, while nowadays only 1000 hectares of high-stem orchards are left in the province Gelderland and about 700 hectares in the province Utrecht and Zuid-Holland (LETS Utrecht 2004).

Grass is expected to grow without reduction for the first 7 to 10 years in agroforestry systems (Newman and Adams 1997, Oosterbaan et al. 2001). Clason and Sharrow (2000) mention that trees have little impact upon forage production until their combined canopy cover exceeds 35 %. Forage yields tend to drop off quickly as canopy cover and tree basal area increase above that value. In an agroforestry experiment in the Netherlands with poplar and
grass (Edelenbosch 1994) little or no yield decrease was found for grass at age 4 at 404 trees/ha (4.5 m x 5.5 m). With the grass intercrop, the poplars did show a decreased growth of 30 % at DBH (diameter at breast height) and 10 % in height, comparable with the growth in one growth season.

Some grass species may fit better in agroforestry systems than others. Certain shade tolerant grasses are even able to grow under a full tree cover (Garrett and Harper 1999, Gordon and Williams 1988, Oosterbaan et al. 2001). Oosterbaan et al. (2001) make notice of studies, which suggest that the shade tolerant species Agrostis tenuis and Dactylis glomerata are most suitable for silvopastoral systems with pine trees. In Missouri, Garrett and Harper (1999) found that Dactylis glomerata, Bromus inermis, Festuca arundinacea, Agrostis gigantea and Phalaris arundinacea were most shade tolerant.

In the Netherlands, Bakker (1960) found that Agrostis tenuis, A. stolonifera and Dactylis glomerata strongly preferred the border strips along poplar plantings. High-quality grasses such as Lolium perenne, Festuca pratensis, and Poa trivialis could easily maintain themselves among grasses of lower quality in the border regions, probably owing to its excellent fertility.

In a sowing experiment of a 25-year old poplar plantings (9 m x 9 m) with different grass-mixtures, Bakker (1960) found that Dactylis glomerata maintained itself well. The percentage Poa trivialis remarkably increased, probably caused by high soil-nitrogen contents. The valuable grass species Lolium perenne and Festuca pratensis decreased their share. This decrease was only slow however, indicating that L. perenne and F. pratensis have a high tolerance to shady conditions as compared to Poa pratensis, Phleum pratense and Trifolium repens (white clover), which could hardly maintain themselves in the mixture. Bakker recommended a mixture of mainly good grasses as Lolium perenne, Festuca pratensis, Poa trivialis and a small amount of selected Dactylis glomerata (22,7,6,5 kg/ha respectively) for sowing poplar pastures.

It can be concluded that high quality grasses can be grown without considerable production losses as an intercrop in the first 10 years of an agroforestry systems, depending on the tree density. Although valuable grass species are able to maintain for longer periods under trees, with increasing crown cover and thus increasing shade, the species composition will gradually shift to more shade tolerant grass species, which are usually of a lower quality (Oosterbaan et al. 2001). Sharrow (1997) on the other hand, mentions that forage grasses under shady, low wind environment near trees tend to mature more slowly. As a consequence they have a lower fibre content and are more digestible compared to forage species growing in the open.

It should be taken into account that trees may also suffer from competition with dense grass swards for nutrients and water. The ability of plants to withdraw soil moisture and nutrients is strongly associated with the amount of fine roots that they have. Ground vegetation that quickly establishes a dense, shallow, fibrous root system, such as many perennial forages, competes severely with newly planted trees. Young, establishing trees may be killed by drought stress in thick stands of ground vegetation, but substantial reduction in tree growth is more common than actual mortality. Dense stands of brush may reduce the growth of even established trees. Underground competition is particularly harmful for young multipurpose trees that are to produce fruit, since good growth during the first years of establishment are crucial for later fruit production. In a later stage the inhibiting effect of grass on wood growth in certain fruit trees could be useful, i.e. after the tree has attained a sufficient size and profit is more dependent on reproductive (fruit) than vegetative (wood) growth (Dupraz and Newman 1997).

A solution for underground competition may be to start with intercrops that are less competitive and introduce forage at a later stage when tree root systems have well
developed. Dupraz and Newman (1997) make notice of the work of A.H. Hoare, who already wrote on orchard intercropping in 1928 and saw great potential for successional planting and cropping of sweet cherries with vegetables, strawberries, fruit bushes and then finally grassed down with the correct grass species to be grazed by sheep or poultry. When planted on already established pastures, young trees will benefit from two to three years of vegetation control after planting. A commonly used approach when planting trees into established pastures is to spray a strip or circle around trees to provide a one to two meter diameter competition-free zone around each tree (Sharrow 1997).

In silvopastoral agroforestry systems one can choose to let livestock graze the strips of pasture, to mow for hay or silage or a combination of both. Both have their own specific advantages, disadvantages and problems, which will be treated in the chapters below.

5.2.3.2 Forage production for hay or silage

The advantage of hay or silage production is that no expensive fencing or protection is needed to avoid trees being damaged by livestock. In forested regions however, it may remain necessary to fence the agroforestry plot to protect young trees from browsing by wild animals such as deer. When one makes the choice for hay or silage, the agroforestry design must match the available machinery (i.e. the machinery must fit easily in between the rows). Furthermore one has to take into account the reduced efficiency, compared to treeless forages. The work will take longer, since one has to circle around the trees and one will harvest a few percents less (Oosterbaan et al. 2004). Research of Oosterbaan et al. (2004) showed that a narrower spacing of trees (10 x 10 m) results in more tree damage and increasing costs of harvesting (more time needed per ha), as compared with wider a spacing (20 x 20 m).

Finally, the specific microclimate invoked by the presence of trees (shade, decreased wind circulation), especially with close spacing and high crown-cover could increase the drying period of mown grass. The latter complicates the hay making. Silage might be an alternative.

5.2.3.3 Pasture

Sheep, goats, cattle and horses

In pastures, trees provide shelter for livestock, especially during periods of inclement weather. This can significantly improve animal performance during particularly hot or cold times of the year. As such trees contribute to the well-being of the livestock, which in return may lead to an economic benefit (Section 3.2.2).

Grazing animals are known to be able to severely damage young trees by trampling, browsing and debarking, if not well protected. Age and experience of animals is probably more important than breed in predicting the willingness of livestock to browse or debark trees. Young animals and those with a past experience of eating tree foliage are much more likely to browse trees (Sharrow 1997). Goats will generally consume more browse than will cattle or sheep and are generally more difficult to graze among young trees (Clason and Sharrow 2000). Hawke and Knowles (1997) mention that livestock can be ‘trained’ to graze among trees. Livestock not accustomed to trees usually cause initial damage, but such damage declines with regular grazing. Browsing damage can sometimes be eliminated by removing a few problem animals. Browsing by livestock is unlikely to kill young trees unless it is both severe and repeated several times.

Since deciduous species are more palatable than pine trees, these will be more vulnerable to browsing. To get valuable timber wood it will be necessary to get straight logs and hence it will be necessary to protect trees during the establishment phase. Once the top branches of trees grow above the reach of livestock and a thick layer of bark has developed, potential for
tree damage by livestock browsing is minimal and agroforests may be managed similar to pastures (Sharrow 1997).

It is possible to protect young silvopastural trees from livestock by means of fencing, electric wire or individual tree shelters. Other options are to cut hay/silage or to grow crops until the trees are well established and introduce livestock as soon as the trees are well established.

In the last 15 years plastic tube-like tree shelters have gained wide acceptance in France and the UK, but the experiences with these are not always good. Reduced growth and poor form in trees when they emerge from the shelter are some of the reported problems (Dupraz and Newman 1997). Improvement of shelter have partly solved this problem. However, tree protection remains expensive and may cost more than the value obtained from the increased grazing. Nonetheless the hindrances mentioned, most of the ‘trees on pasture’ plantations in Europe have been made possible through the use of such shelters (Dupraz and Newman 1997).

When one has the choice though, it will probably be more cost-effective to only introduce grazing animals after a couple of years, when trees are well established and are grown well above the height of the livestock. Slow growing species and species with thin and palatable bark, such as cherry, are more sensitive for damage and will need a longer protection than more robust trees. Repellents or an abrasive paint-on applied to the tree stem may also be effective to avoid tree debarking (Dupraz and Newman 1997, Williams et al. 1997). Nair (1993) indicates that even in early years in pine plantations, livestock may be allowed to graze during seasons when the nonconifer vegetation is more palatable than tree seedlings. In general livestock should be removed as soon as fodder becomes short, to prevent bark damage to the trees (Clason and Sharrow 2000, Sharrow 1997).

Poultry, pigs, deer
More and more people nowadays are choosing free range or biological eggs and (to a lesser extent) meat. This expanding market may be an interesting option for agroforestry.

Chickens originate from forest species and thus feel best in such environment. Evidence suggests that our modern poultry breeds still prefer tree/shrub cover to the open grass ranges currently favored by farmers. Certified free range meat chickens are provided with at least 1 m² surface in the open air each. Certain types of free range hens and all biological poultry are given 4 m² each at least (Biologica, 2004). However, in existing free range poultry systems, chickens appear to be reluctant to range, even when the very best ranging conditions are provided (artificial shelters, fences, hedges etc.). In a recent study, no more than 14% of chickens were observed to leave the house at any one time (Northmore trust, 2004). In the UK, very recently various projects are set up with agroforestry systems for chicken production (Northmore trust, 2004, Philipps et al. 2002). It is expected that the woodland environment will encourage ranging and more natural behaviour and thus lead to an overall benefit in poultry welfare. Commercial performance of the birds may be improved as a result of this welfare enhancement. Additionally herbs could provide nutrition and medicinal benefits for them. The environment should offer the poultry increased protection from aerial predators, so either high density plantings or established agroforestry systems where tree crowns are at least partly closed.

The presence of poultry will also have advantages for the trees. Competing undercover will be controlled, reducing the need for herbicides and manual input and tree growth will be improved by fertilization from poultry manure. Furthermore poultry may help in insect control and will clean fallen fruits, nuts and other organic wastes. Poultry will not damage the trees, so expensive tree protection will not be necessary.
Although few examples of such practices are found in temperate regions nowadays, it is likely that other free range animals for meat-production can be introduced in agroforestry systems. Pig, turkey and deer are all forest species in nature and will, thus, benefit from trees in their free range area. In Spain and Portugal, pigs are commonly kept in extensive agroforestry systems with cork-oaks, where they feed on the acorns (Dupraz and Newman 1997). The pig meat from this system has a special flavor which is highly valued and makes a good price on the market. In Norway, the elm is traditionally used as a feed for livestock. In the past, acorns from the forest were used as pig feed in the Netherlands as well. Oaks however have an irregular pattern of fruit production and acorns are short in proteins, which makes them not the ideal feed. It may, however, remain valuable as an additional feed to obtain the special flavor. Honeylocust (Gleditsia triacanthos) has been proposed as a better species to produce feed for animals (Section 4.3.1). With this tree an integrated feed and meat production system may even be possible in the Netherlands.

5.3 **Smallfruit**

5.3.1 **General**

Many berry species originate from the forest or forest-edge and may, being used to (partial) shade, have a good potential as intercrop. Nevertheless, for most berries a reasonable amount of sunlight must be available to ensure good fruit production. Gooseberries and currants perform good in partial shade, other small-fruit need at least six ours direct sun a day, preferably more (Eames-Sheavly et al. 2003).

The area of woody smallfruit in the Netherlands has strongly decreased since the 60’s, caused by the increased competition from Eastern Europe, in particular the production for processing industry. From 1979 Dutch production stabilized at about 500 ha spread over the country, mainly for fresh consumption. An exception form the black currant and the blueberry, which are mechanically harvested. Most other berries are cultivated on small areas on small farms, making mechanization and cultivation measures suboptimal (NFO 1990).

For the marketing of fresh fruits, it is important to strive for an optimal spread of harvest. Outside the traditional harvesting season, best prices are paid for the product. Farmers can adapt to this by choosing the right cultivars. This is a better solution than the cultivation in plastic tunnels to accelerate or delay harvest, which is accompanied with problematic crop protection.

Almost all races of woody smallfruit are vulnerable for various diseases, while only a limited array of pesticides is permitted. The fungus botrytis can cause severe damage to all small-fruit crops. Root disease, caused by *Phytophthora megaspora* is a big problem with raspberries. Maybe a more natural cultivation under agroforestry will decrease disease pressure and thereby minimize the harvest risks of woody small-fruit.

5.3.2 **Well known species**

*Vaccinium* spp.

The heigh bush blueberry (*Vaccinium corymbosum*) and cranberry (*Vaccinium macrocarpon*) originate from N-America. The bilberry (*Vaccinium myrtillus*) is an indigenous species in the Netherlands. Cranberry and bilberry stay low and can form a good groundcover. Heigh bush blueberry grows up to 2 m high. Their fruits are rich in vitamin C, they can be eaten raw or cooked and used in pies, pastries, cereals and jellies. They can also be dried.
All three species thrive on poor acid peaty soils and can grow both in sun and in half shade (Huese 2000), but they fruit better in a sunny position though (PFAF 2004). The need for acid peaty soils limits their combination with trees in agroforestry systems. Although these species could be grown in association with pine trees on peaty soils, most multipurpose or short rotation trees mentioned in Chapter 4 will not grow well on acid peaty soils.

*Ribes* spp.
The genus comprises gooseberries (*Ribes grossularia, R. hirtellum, R. uva-crispa*), black (*Ribes nigrum*), red and white currants (*Ribes rubrum*) and worcesterberries (*Ribes divaricatum*). The jostaberry, a cross between the gooseberry and black currant has also proven its value; it has the fastest growth of all species, is resistant to various berry diseases and yields 5-8 kg of big black fruits per shrub.

This genus is probably one of the best for the shady lower storey of temperate agroforestry systems, since they are woodland plants in their native state. Good experience has been reported on their cultivation under trees. Hart (1996) reports that a traditional form of agroforestry practiced in the Fen area of Eastern England has been the growing of gooseberries in orchards. There are many varieties of gooseberries available, but for the forest garden he specially recommends “Whinhan’s Industry”, as it is specially shade-tolerant. Possibly old races are more shade-tolerant than modern varieties.

Also black currants are traditionally found in agroforestry systems in the British West Country, being interplanted with plums. Shoemaker (1955) mentions that currants and gooseberries are sometimes used as intercrop in intensive orchard systems. The shade is of some benefit, particularly to the gooseberry. He writes “where trees are set 20 feet apart there is room for only one bush between each pair of trees and it is questionable whether there is enough space between tree rows for a row of cane fruit. At greater distances, about 24 feet, there would be enough room for 2 bushes between each pair of trees and also for a full row of cane fruits between the rows of trees. At larger distances, more of the cane fruits can be set both in and between rows”.

Gooseberries and currants grow on a variety of soils, but they prefer fertile airy humus rich soils that can hold sufficient moisture. Sites with poor air-circulation, which increases the incidence of powdery mildew, should be avoided. For gooseberries, races that are more resistant to American mildew have come available, which offers good opportunities for its cultivation in agroforestry systems. Fresh consumption of red and black currants have increased in recent years, indicating that there is a market for such products.

*Rubus* spp.
Raspberry, blackberry and Japanese wineberry (*Rubus phoenicolasius*) are the most cultivated species of this family. The first two are indigenous species, the Japanese wineberry originates from E-Asia. All berries can be grown as hedges of 1,5-2 m high (Neerlands tuin, 2004).

Both raspberries and blackberries like fertile soils. Raspberries prefer humus rich soils or calcium rich clay with humus added. Fertilization is not necessary, since the more nitrogen, the less taste and the harder to keep them fresh. Compost is best. Blackberries prefer high N-gifts and humus rich moist soils. On shady places they flower bad and yields are low. Furthermore the taste is less or the berries will hardly ripen. They will thus grow best in young agroforestry systems or on the southern side of tree rows. The Japanese wineberry looks like the blackberry, but grows less wild and is good to lead. It is an easy shrub, which hardly knows diseases. It needs a place in the sun or half shade and grows on all soils, preferably humus-and calcium rich.
5.3.2 Less known species with potential

There are various temperate berry species that may have potential for the Netherlands. Most of these will have potential for small scale cultivation only, and for sale on regional markets, delicacy shops or restaurants. Their real market potential should be further explored and developed in the Netherlands.

**Actidinia spp. (Kiwi fruit)**

Actidinia species are fruiting climbers from China and elsewhere in the Far East. The “Chinese Gooseberry” is most commonly eaten in the west as kiwi-fruit. Since they are climbers, they will need to be trellised for easy picking. In China, *Actidinia* species are multi-purpose plants. Oil can be extracted from the seeds, the leaves are rich in starch, the roots are used medicinally, the fibers are used in paper-making and the abundant resin is used for dyes and plastics (Hart 1996).

The commercially available kiwi is probably not the best *Actidinia* for the Dutch climate, because of its cold-tenderness and long growing season. A cousin of this kiwi, though, the hardy kiwi (*Actidinia arguta*), originates from Siberia and is much more cold hardy. This species has interesting properties such as its good flavor, relatively smooth (and edible) skin and “out of hand” eating size (about the size of a large grape). In temperate regions in France and the USA, commercial plantations have been established already, but the growing of hardy kiwi remains an experiment (Pennsylvania State University 2001). The small fruit size, limited ripening period and shorter shelf life are market limitations and have so far kept acreage limited in France (Strik and Cahn 2000). Cultivar development is in its infancy, because of the newness of this crop, but some cultivars of the hardy kiwi are available.

Although very hardy, the hardy kiwi is susceptible to late frost. Vines perform best in full sun, but on such sites they tend to break dormancy too early in the spring, when late frost can damage new growth. Eames-sheavly et al. (2003) therefore recommend a Northern exposure to delay early growth and minimize these risks. The succulent growth furthermore is susceptible to wind damage and hot, dry conditions. Protected moderate microclimates are best, as the kiwi does not like sudden temperature changes. These properties seem to make the hardy kiwi especially suitable for temperate agroforestry systems.

Kiwifruit grows on all soils with a pH between 5.5 and 7. It thrives in moist soils, but does not tolerate poorly drained soils. It benefits from the incorporation of organic matter before planting. There are some important horticultural limitations on the cultivation of hardy kiwi’s though. Actidinia’s are dioecious, so both males and females must be planted to get fruit. Furthermore the plants often take several years to mature, and usually do not bear fruit until they are 5 to 9 years old. Finally hardy kiwi are extremely vigorously growing vines, requiring a substantial supporting trellis, otherwise they will grow up the trees (Pennsylvania State University, 2001).

Elaborate information on cultivation is available from Strik and Cahn (2000).

**Gaultheria hispidula** and **G. humifisa** (Creeping snowberry and Alpine wintergreen)

These two species from N-America, closely related to the *Vaccinium* species, stay low and are a useful fast growing ground cover plant for shady places. The small fruits are eaten raw or cooked or can be made into preserves. Also the leaves can be eaten or used for tea (PFAF 2004). These plants prefer light (sandy) and medium (loamy) soils, which are acid or neutral and can grow in very acid soil. They grow well in semi-shade and require moist or wet soil. Just like *Vaccinium*, these plants like acid peaty and lime-free soils, which makes them most suitable for combination with pine trees.
Gaylussacia baccata (Black huckleberry)
Also this plant is a N-American relative to the Vaccinium species. It grows up to one meter high and its fruits are used raw, cooked, dried or made into pies and preserves. The plant grows on both sand, loam and clay soils, but prefers acid soils and can grow in very acid soil. It can grow in sun or semi-shade. It requires dry or moist soil that are well drained.
For their preference for acid soils, they will combine best with pine trees. Also other species of Gaylussacia form edible fruits and may be useful in a similar way (PFAF 2004).

Myrica carolinensis (Bayberry)
This shrub (up to 3 m) from N-America gives edible fruits and leaves. The leaves are used as a condiment in dishes. The plant has medicinal properties as well. Furthermore a dye is obtained from the leaves and fruits and the wax on the fruits is extracted to make candles (PFAF 2004). It grows on lime-free loamy or peaty soils that are moderately moist to wet. It grows in sun and half shade (Huese 2000). The plant is very wind hardy and can be grown in hedges.

Cornus canadensis (Creeping dogwood)
Most Cornus species are trees that form small fruits (see 4.3.1). Especially suitable for agroforestry purposes seems Cornus canadensis from N-America. This beautiful creeper gets only 20 cm. tall and needs half shade to form a good groundcover. It is a very good dense ground cover plant and when established they can spread 60 - 90cm per year. The plant grows in most soils, if moist and can grow in heavy clay soil. The plant prefers acid and neutral soils (PFAF 2004).
In September/October it forms clusters with 4-7 long round berries, which are a delicacy. The fruit is rich in pectin and the Laps of Northern Scandinavia make them into a fruit-jelly which is used in pudding.

Viburnum trilobum, V. edule and V. opulus var. americana (Highbush cranberries)
These highly ornamental bushes grow up to several meters tall and can be made into hedges. The size and color of the fruit are the only similarities with normal cranberries. The fruits are rich in vitamin C, they are an excellent substitute for cranberries and are used in preserves, jams, jellies and sauces. The fruits are about 1 cm, showy red and very persistent, remaining on the bushes well after frost. Some authors mention that to avoid astringency, fruits are best harvested in summer or autumn (Eaves-Sheavly et al. 2003). Other sources note that fruits taste best after frost (PFAF 2004).
They perform well on a range of soils and can even grow on heavy clay. They tend to decline with too much moisture stress though and prefer a deep rich loamy soil in sun or semi-shade (PFAF 2004).

5.4 Specialty crops
Many specialty crops have a high potential as agroforestry intercrops, many even in shady conditions. Specialty crops automatically also means that specialty markets are necessary; often products are marketed only on a small scale or marketing channels may not even developed yet in the Netherlands. For many of these crops markets should be sought for in specialty shops, local restaurants or in the form of regional products.
5.4.1 Woody ornamentals

Conifers
Various coniferous species are well able to grow in partial shade. Especially the cultivation of Christmas trees may be a good option as one of the intercrops, or as temporary plantings in tree lines. A secondary advantage of such intercrop is that it will support a straight growth of the main tree species and prevent knots, resulting in valuable logs and decreased pruning costs. Planting in the tree line of fast growing species as poplar may be less suitable, as these will quickly cast too much shade, forcing the coniferous trees to make more open crowns (longer internodes) which makes them unsuitable as Christmas tree (Oosterbaan, pers.comm 2004, Alterra, Wageningen).

Bamboo
Many bamboo species could be grown in an agroforestry environment. They are ideal woodland plants and often prefer growing in a dappled shade. They are shallow rooted and hence are good to combine with deep rooting trees. An additional advantage of growing bamboo as an intercrop may be that they support the straight growth of the tree and decrease the necessity of pruning to get straight logs.

There are innumerable species and just as many uses of bamboos. The bamboo sticks can be used for supporting trees, making furniture, paper, construction, water tubes and many other utensils. The young shoots can be eaten and may have potential to be marketed as a specialty food in the Netherlands. Nice stalks and the whole plant can be marketed as ornamentals. Although many species are suitable for the Dutch climatic conditions, probably the best all-rounder is the genus Phyllostachys, which produces the nicest and largest edible shoots and very good quality canes (Fern 1997). They usually prefer a moist soil.

For specific information on species habits and requirements referred is to Fern (2000) and PFAF (2004).

5.4.2 Herbaceous ornamentals

Ferns
Many ferns originate from moist and shady wooded environments and as such are excellent intercrops for established forests and older agroforestry systems when shade no longer permits other crops to grow. Ferns can be sold as whole plants or the leaves can be cut for use in ornamental pieces and bouquets.

Flower bulbs
Many ornamental bulbous species come from (partly) shaded forest environments. Most shade tolerant or shelter-demanding flower bulbs could be cultivated as intercrops as long as shade is not too dense. Some bulbs even demand shaded environments for good growth or have most of their growth in early spring when trees are still leafless. These species are especially suitable for integration in aged agroforestry systems when most crops are out shaded. Table 5.1 gives a selection of bulbous ornamentals with potential in agroforestry and their specific demand regarding light and soil.

It must be noted however that this list is not complete; probably many more bulbous species can be cultivated in agroforestry environments. Also the more conventional light demanding species may well fit in the early stages of agroforestry systems. Since most bulbous species
have a relatively small and superficial root system, it can be expected that these will cause rather low below ground competition with the tree.

Table 5.1: Growth requirements of flower bulb species with potential for AF

<table>
<thead>
<tr>
<th>Species</th>
<th>Growth place</th>
<th>Soil type</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Allium spp.</em> (ornamental onion)</td>
<td>Sun/half shade</td>
<td>All soils</td>
</tr>
<tr>
<td><em>Anemone spp.</em></td>
<td>Everywhere</td>
<td>Sand, sandy clay, clay</td>
</tr>
<tr>
<td><em>Arum italicum</em></td>
<td>Sun-half shade-shade</td>
<td>All soils</td>
</tr>
<tr>
<td><em>Camassia spp.</em></td>
<td>Everywhere</td>
<td>Sand, sandy-clay, clay</td>
</tr>
<tr>
<td><em>Chionodoxa spp.</em></td>
<td>Everywhere</td>
<td>All soils</td>
</tr>
<tr>
<td><em>Colchicum spp.</em></td>
<td>Everywhere</td>
<td>All soils</td>
</tr>
<tr>
<td><em>Corydalis cava, Corydalis solida</em> (fumewort)</td>
<td>Halfshade</td>
<td>Sand, sandy clay, moist</td>
</tr>
<tr>
<td><em>Crocus spp.</em></td>
<td>Sun/half shade</td>
<td>All soils</td>
</tr>
<tr>
<td><em>Eranthis spp.</em></td>
<td>Sheltered (especially E. hyemalis under trees)</td>
<td>All soils (high O.M.)</td>
</tr>
<tr>
<td><em>Erythronium spp.</em></td>
<td>Sheltered from wind</td>
<td>Sand, sandy clay</td>
</tr>
<tr>
<td><em>Fritillaria meleagris</em></td>
<td>Half shade</td>
<td>All soils, humus-rich, moist</td>
</tr>
<tr>
<td><em>F. michailovskyi</em></td>
<td>Everywhere</td>
<td>All soils</td>
</tr>
<tr>
<td><em>F. persica</em></td>
<td>Sheltered from the wind (length)</td>
<td>All soils</td>
</tr>
<tr>
<td><em>Iris danfordiae/reticulata</em></td>
<td>Sun/half shade</td>
<td>All soils</td>
</tr>
<tr>
<td><em>Lilium candidum</em></td>
<td>Sun/half shade</td>
<td>Sand, sandy clay, pH&gt;6</td>
</tr>
<tr>
<td><em>Muscari spp.</em></td>
<td>Sun-half shade</td>
<td>All soils, moist</td>
</tr>
<tr>
<td><em>Narcissus spp.</em></td>
<td>Sun-half shade</td>
<td>All soils, moist</td>
</tr>
<tr>
<td><em>Ornithogalum umbellatum</em></td>
<td>Sun-half shade</td>
<td>All soils, moist</td>
</tr>
<tr>
<td><em>Puschkinia scilloides</em></td>
<td>Everywhere</td>
<td>Sand, sandy clay, clay</td>
</tr>
<tr>
<td><em>Scilla spp.</em></td>
<td>Everywhere</td>
<td>All soils</td>
</tr>
<tr>
<td><em>Zantedeschia spp.</em> (not winter hardy)</td>
<td>Everywhere</td>
<td>All soils, well drained</td>
</tr>
<tr>
<td><em>Convallaria majalis</em></td>
<td>Shade</td>
<td>All soils</td>
</tr>
<tr>
<td><em>Galanthus spp.</em></td>
<td>Light in spring, shade after flowering (deciduous trees)</td>
<td>All soils</td>
</tr>
<tr>
<td><em>Hyacinthera bletilla striata</em></td>
<td>Shade</td>
<td>All soils</td>
</tr>
<tr>
<td><em>Hyacinthoides non-scripta</em> (blue bell), H. hispanica*</td>
<td>Half shade</td>
<td>All soils</td>
</tr>
</tbody>
</table>


*Rosa spp.* (Roses)

Roses in their natural state grow on the forest edge and can thus be expected to grow well in partial shade. Many rose varieties are grown nowadays, mostly in full light. Probably most modern varieties will not be very productive when grown in partial shade and one should look for varieties that can still adapt to shady conditions for application in agroforestry systems.

Apart from their ornamental value, roses have exceptional nutritional and medicinal value. The hips are one of the richest sources of vitamin C, beneficial for female ailments and can be made into juice, jams, syrup and tea. Some varieties produce hips that can be eaten raw. Wild and traditional varieties are more medically potent and often more fragrant than the modern ornamental varieties (Hart 1996).

The Japanese *Rosa rugosa* produces large round hips, which are edible. It grows good in all soils if well drained, even in heavy clay soils. It fits very well in the coastal areas, since it is resistant to the sand and salt from the wind. It is a healthy shrub, resistant to most typical rose diseases. It can be grown in hedges and grows up to 1.5 m high and 1 m wide, both in semi-shade and full sun (Neerlandstuin 2004, PFAF 2004).
Other ornamental plants
Many other plants, which are locally marketed as pot or garden plants, may have potential for cultivation in agroforestry systems as they benefit from the shade or the microclimate. Hundreds of species of hardy ferns for instance originate from moist and shady wooded environments and as such are excellent intercrops for established forests and older agroforestry systems when shade no longer permits other crops to grow. Other examples are various mosses, ornamental grasses and an endless range of shade-tolerant hardy plants, e.g. *Rhododendron*, *Aconitum* spp., *Ajuga* spp., *Bergenia* spp., *Buxus* spp., *Campanula* spp., *Clematis* spp., *Digitalis* spp., *Epimedium* spp., *Euphorbia* spp., *Geranium* spp., *Hosta* spp., *Liguria* spp., *Persicaria* spp., *Primula* spp., *Saxifraga* spp., *Tiarella* spp., *Veronica* spp., *Viola* spp. and many others. Many of these have medicinal or edible properties as well and may thus serve various purposes and markets. Some may be partially harvested for their greenery, others may be cultivated in (dug in) pots and sold as such.


5.4.3 Medicinal plants, herbs and aromatics
A wide range of forest plants are marketed as medicinals or as dietary supplements. They are used in the manufacture of medicinal compounds, teas, oils, powders, food and flavorings. Therapeutic qualities may be found in any plant organ, but mostly in roots. Medicinal and dietary supplements form the largest segment of the non-timber forest products (NTFP) industry. Chamberlain and Hammett (1998) mention that the estimated global market for herbal medicines in 1996 was estimated at a value of 14 billion U.S. dollars, half of which was represented by Europe. Markets for medicinal plants that are collected from the forest are growing rapidly and some species are subject to overharvesting (Hill and Buck 2000, Chamberlain and Hammett 1998). It has been proposed to set aside areas of forest which can be farmed intensively for production of desirable forest-dependent species (Cech 1998). Such initiatives are already taken on a large scale in North-America, in the form of forest farming in hardwood forests. Although no such examples are found in the Netherlands, the cultivation of valuable botanicals, either in existing forests or in specifically designed agroforestry systems, may have great potential.

The British Agroforestry Research Trust (ART 2004) gives a selection of medicinal plants, shrubs and trees which can be grown under the protection of a forest canopy in temperate zones. For these species 5-40 % crown cover should be a desirable crown cover (Table 5.2). This is a selection of only some of the species which are of medical interest and fit in an agroforestry environment. Many essential oil crops can also be cultivated in semi-shaded conditions, e.g. mints, lemon balm, thyme.

Both Hill and Buck (2000) and Chamberlain and Hammett (1998) give a list of medicinal plants that are traded as medicines and dietary supplements and inhabit American forests. Most valuable and already cultivated in American forest farming systems, are ginseng (*Panax quinquefolius*) and goldenseal (*Hydrastis canadensis*). They grow in similar habitats; moist, rich, deep shaded deciduous woods. Other highly valuable medicinal species, which are known to have been cultivated, are echinacea (*Echinacea purpurea*), black cohosh (*Cimicifuga racemosa*), blue cohosh (*Caulophyllum thalictroides*) and bloodroot (*Sanguinaria canadensis*). These are all root species. Black cohosh is easy to grow and thrives under lightly shaded conditions in a rich, moist forest soil. Blue cohosh and bloodroot can be grown in similar habitats to that for ginseng and goldenseal. Blue cohosh is not subject to pests, requires a minimum of care and
is a good candidate for commercial cultivation (Hill and Buck). Echinacea grows in open woods and likes a moderately rich, well drained soils, and is drought resistant. *Ginkgo biloba* (maidenhair tree), *Hamamelis virginiana* (witch hazel), *Celastrus scandens* (bittersweet) are species whose active properties are not in their roots. They are in high demand and could be easily cultivated in intensively managed settings (Hill and Buck 2000). *Taxus baccata*, which is a source for anti-cancer drugs, may also be considered usefull for agroforestry, as it grows very slowly and stands regular pruning.

### Table 5.2: List of some medical plant species with potential for AF

<table>
<thead>
<tr>
<th>Species</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adonis vernalis</td>
<td>Spasmolytic, sedative</td>
</tr>
<tr>
<td>Agrimonia eupatoria</td>
<td>Antiviral, anti-inflammatory</td>
</tr>
<tr>
<td>Ammi majus</td>
<td>Antispasmodic, anti-inflammatory</td>
</tr>
<tr>
<td>Anabasis aphylla</td>
<td>Antipyretic, anti-inflammatory</td>
</tr>
<tr>
<td>Anisodus tanguticus</td>
<td>Anti-inflammatory</td>
</tr>
<tr>
<td>Artemisia annua</td>
<td>Antimalarial, analgesic</td>
</tr>
<tr>
<td>Artemisia maritima</td>
<td>Anti-inflammatory</td>
</tr>
<tr>
<td>Atropa bella-donna</td>
<td>Narcotic, hallucinogenic</td>
</tr>
<tr>
<td>Berberis vulgaris</td>
<td>Anti-inflammatory, antiseptic</td>
</tr>
<tr>
<td>Brassica nigra</td>
<td>Antispasmodic, expectorant</td>
</tr>
<tr>
<td>Colchicum autumnale</td>
<td>Antirheumatic, antipyretic</td>
</tr>
<tr>
<td>Convallaria majalis</td>
<td>Antirheumatic, sedative</td>
</tr>
<tr>
<td>Coptis japonica</td>
<td>Antirheumatic, anti-inflammatory</td>
</tr>
<tr>
<td>Corydalis ambigua</td>
<td>Antispasmodic, analgesic</td>
</tr>
<tr>
<td>Cynara scolymus</td>
<td>Anti-inflammatory, cholesterol lowering</td>
</tr>
<tr>
<td>Cytisus scoparius</td>
<td>Antispasmodic, sedative</td>
</tr>
</tbody>
</table>


Cech (1998) notices that ginseng is widely cultivated, while goldenseal cultivation is poorly understood and lags far behind demand in North America. He indicates that the cultivation of goldenseal is “unquestionably the most significant current herbal agricultural opportunity”. He also expects increasing opportunities for the commercial cultivation of black cohosh. Hill and Buck (2000), indicate that the cultivation of goldenseal is easier and has several advantages over ginseng, as it can be harvested in three years (compared to five or more), is easier to propagate and not subject to the disease and pest problems often related to ginseng cultivation.

Since much of the wild-crafted and cultivated botanicals in North America are meant for the export market to Europe and especially Eastern Asia, it is probable that marketing of these species in temperate Europe will not be a problem. Further esearch is needed to test if these species can be cultivated outside their natural habitat, since successfull cultivation of any forest-dependent species will require specific conditions of shade, soil and season.

Cultivation of forest species in circumstances close to its native ecology is more likely to succeed than attempts to cultivate species in artificial environments or outside their native range. Consequently the cultivation of medicinal species from temperate Europe should be a good choice. Although little information is found on the commercial cultivation of valuable medicinal species in forest environments in temperate Europe, it is probable that opportunities for the cultivation of such species in agroforestry systems exists. Various medicinal species, such as *Digitalis purpurea*, *Convallaria majalis*, *Valeriana officinalis* and *Atropa belladonna* are found in Dutch forests, are cultivated and marketed for their medicinal properties and hence could have great potential for cultivation in the semi-natural environment of agroforestry systems. Market demands and prices paid for these plants may...
however be lower than those of popular herbals as ginseng, goldenseal, black cohosh and *Ginkgo biloba*.

Ginseng is one of the most valued herbal medicines and much information is available on its cultivation. The following therefore explores its requirements, properties and economic value, in order to determine its potential for cultivation in Dutch agroforestry systems. For more elaborate information on medicinal species, their properties and requirements, referred is to PFAF (2004), ART (2004) and Hill and Buck (2000).

**Panax spp. (Ginseng)**

Various species of ginseng exist, of which the Oriental or Asiatic ginseng and the American ginseng are most well known (*Panax ginseng* and *Panax quinquefolius* respectively). Asian ginseng has a history of herbal use going back over 5,000 years. It is one of the most highly regarded of herbal medicines in the Orient, where it has gained an almost magical reputation for being able to promote health, general body vigor and also to prolong life. At present, ginseng is widely cultivated in the U.S., Canada, and China. In natural conditions, the seed may take two or three years to germinate and another three to four years to produce seed. At this age the ginseng roots can be harvested (Sadler 1999).

The North American species of ginseng is said to have similar properties to the Asian ginseng, though it is said to have a milder action. The root is harvested in the autumn and dried for later use. It is found in rich woods from Quebec to Minnesota and South Dakota to Georgia and occurs in Louisiana and Oklahoma. It grows in full shade underneath deciduous hardwood species, typically in calcium rich forest soils well supplied with organic matter (Anderson 2003). Davis (1997) recommends 75-85 % shade and planting should thus be done in an established forest or agroforestry system, where canopies are well developed. Deeply rooted deciduous trees, such as walnut, poplar, oak and basswood are best for shading ginseng. Shallow rooted trees should be avoided because they offer serious competition for soil moisture and nutrients and ginseng establishment will be difficult and growth very slow. Cornell cooperative extension (2001) reports that Ginseng grows well in mixed hardwood forests, with a predominance of sugar maples. Sugar maple leaves retain their calcium when they die and fall off the tree, enriching the soil below. They also pull water up with their tap roots, which the ginseng can use.

Ginseng grows well on deep moist, but well-drained soils, since wet conditions often result in rotting of the Ginseng roots. Ideally are loamy and humus rich soils, but in fact the plant tolerates a wide variety of soils, except heavy clay or light sand.

Apart from wild ginseng, which is a protected species, three types of ginseng are considered for medical use (Beyfuss 1999):

- Field cultivated ginseng is grown in raised beds in fields under artificial shade provided by either wood lathe or polypropylene shade cloth for a period of three to four years.
- Woods cultivated ginseng is grown in a forested environment in tilled beds under natural shade for a period of six to nine years.
- Wild simulated ginseng is grown in untilled soil in forests for a period of nine to twelve years or even longer. The dried roots of wild simulated ginseng closely approximate the appearance of truly wild ginseng.

Both the seeds and the roots are valuable. Under artificial shade yields of 75-100 kg of seeds in the third and 250 kg in the forth year are possible. Roots in these well managed circumstances can yield up to 1,500 kg (air dried weight) per acre. Naturally shaded plantings of comparable cultural intensity are not likely to yield more than two third as much (Davis 1997). With good growth, roots may be harvested after 4 years in artificially shaded gardens. In naturally shaded plantings harvesting may need to be delayed until the eight year or later.
There is little reliable information on the economics of ginseng. There is a great range in cultural practices with various intensities. Moreover, the economic analysis methods differ. Davis (1997) gives two estimates, based on various sources (table 5.3). The first refers to one acre of ginseng grown in the woods and harvested after 6 years of growth. The second refers to ginseng intensely cultivated under polypropylene shade. Beyfuss (1999) made similar estimations for wild-simulated ginseng and woods-cultivated ginseng (table 5.4). Persons (1998) gives similar figures as Beyfuss (1999), with slightly lower profits.

If we reverse the figures in table 5.3 and 5.4 in euro/ha (1 acre = 0.4 ha, 1 $ = € 0.83 at 22/6/04), than the net income for woodlands cultivated ginseng after 6 years would be € 74.700/ha for Davis and € 24.174/ha for Beyfuss. The contrasting figures of Davis and Beyfuss for woods cultivated ginseng are partly due to different prices for labour and harvested roots. Moreover, Davis also takes into account the income of harvested seeds, while Beyfuss does not. Field cultivated ginseng under artificial shade would yield a net income of € 157.700/ha after 4 years and wild-simulated € 67.687/ha after 9 years.

Cornell cooperative extension (2001) mentions that wild simulated ginseng in 1999 was sold for $250/pound dry. Woods grown brought about $150/pound dry and field cultivated ginseng valued at under $20/pound dry in 1999. Ginseng is currently valued based on appearance; if it looks wild it has a higher value. The roots are shaped differently in prepared beds than in undisturbed soil.

Table 5.3: Estimations on the economics of woods cultivated ginseng and of field cultivated ginseng (Source: Davis 1997)

<table>
<thead>
<tr>
<th>Costs</th>
<th>Woods cultivated, 6 years (in $)</th>
<th>Field cultivated, 4 years (in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds ($65 per pound)</td>
<td>3.900 (30 pounds)</td>
<td>6.500 (100 pounds)</td>
</tr>
<tr>
<td>Labor</td>
<td>26.600 (3.800 h at $7)</td>
<td>13,500</td>
</tr>
<tr>
<td>Shade structures</td>
<td>-</td>
<td>14.000</td>
</tr>
<tr>
<td>Equipment and supplies</td>
<td>5.000</td>
<td>4.500</td>
</tr>
<tr>
<td>Drying and packaging</td>
<td>1.500</td>
<td>14.500</td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
<td>37.000</td>
<td>53.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Woods cultivated, 6 years (in $)</th>
<th>Field cultivated, 4 years (in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds ($65 per pound)</td>
<td>13.000 (200 pounds)</td>
<td>39.000 (600 pounds)</td>
</tr>
<tr>
<td>Roots (60.000 per $60 per pound)</td>
<td>60.000 (1.000 pounds at $60 per pound)</td>
<td>90.000 (3.000 pounds at $30 per pound)</td>
</tr>
<tr>
<td><strong>Total benefits</strong></td>
<td>73.000</td>
<td>129.000</td>
</tr>
</tbody>
</table>

| Net income                 | 36.000                            | 76.000                            |

Table 5.4: Estimations on the economics of woods cultivated ginseng and of wild simulated ginseng (Source: Beyfuss 1999)

<table>
<thead>
<tr>
<th>Costs</th>
<th>Woods cultivated, 6 years (in $)</th>
<th>Wild simulated, 9 years (in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds ($75 per pound)</td>
<td>3.600 (48 pounds)</td>
<td>1.500 (20 pounds)</td>
</tr>
<tr>
<td>Labor</td>
<td>38.000 (3.800 h at $10)</td>
<td>12,500 (650 h at $10)</td>
</tr>
<tr>
<td>Equipment and materials</td>
<td>4.650</td>
<td>500</td>
</tr>
<tr>
<td>Drying</td>
<td>1.100</td>
<td>880</td>
</tr>
<tr>
<td><strong>Total cost</strong></td>
<td>48.350</td>
<td>15.380</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Woods cultivated, 6 years (in $)</th>
<th>Wild simulated, 9 years (in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Roots (60.000 per $100 per pound)</td>
<td>60.000 (600 pounds at $100 per pound)</td>
<td>90.000 (80 pounds at $300 per pound)</td>
</tr>
<tr>
<td><strong>Total benefits</strong></td>
<td>60.000</td>
<td>48.000</td>
</tr>
</tbody>
</table>

| Net income                 | 11.650                            | 32.620                           |
Considering the relatively high and long term investments and the unpredictable yields and prices, ginseng appears to be a risky crop. On the other hand it can be very profitable. Regarding the prudent calculations of Beyfuss, woodland-cultivated ginseng would still give a net annual profit of more than € 4000 per ha, which is very high compared to the average net annual profit of € 1000-2000 per hectare of food crops in the Netherlands. It is therefore, recommended to start on a small scale and expand if preliminary results and prices appear to be good.

If the roots of ginseng grown under agroforestry have the appearance of woods cultivated ginseng, the cultivation of ginseng in Dutch agroforestry systems seems to have high potential. However, if agroforestry grown ginseng gets the same price as field cultivated ginseng, ginseng may not be a profitable intercrop. Although the figures of Davis in table 5.3 may predict otherwise, Beyfuss (1999) remarks that in recent years the world market price for field cultivated ginseng has dropped to near the actual cost of production ($ 12-20/pound). The prices of woods cultivated and wild simulated ginseng, on the other hand, have risen to levels that, according to Beyfuss (1999), can be extremely profitable for landowners with suitable forest stands. agroforestry experiments will have to proof if ginseng cultivated under agroforestry will fall under the category of woods cultivated ginseng.

At present, most ginseng is sold to Eastern Asia, but American ginseng is gaining popularity among American and European consumers. Eventually a market for "organic" ginseng can be expected to develop, as western people become more familiar with this product. Woodland cultivation is the only possible way to grow ginseng "organically". Currently, the production of woodland ginseng is so limited that almost all of it is exported to Asian countries.

5.4.4 Specialty vegetables

There are thousands of plants with edible leaves, but the modern world has only focused on very few species, most of which are annuals, such as lettuce, cabbages, and common spinach. Adding less known vegetables to the agricultural landscape, especially perennial vegetables, could contribute to the diversity of the agroecosystem and people’s diet. Many of these species are tolerant to partial or even full shade and as such have high potential for integration in the later phase of agroforestry systems, when light demanding crops are no longer able to grow. Although they may be easily grown and very productive, many of these vegetables cannot be harvested with machinery as used for common annual vegetables. Hence they are usually more labour intensive. Related to this, markets for many of these plants are not yet developed. This makes them most useful for small-scale and innovative farmers and especially suitable for home consumption.

It is impossible to describe all possible vegetables, so chosen is to make a selection of vegetables, which have proven their value (i.e. good growth, yield and taste) in the permaculture and forest gardening movement and which are especially suitable to combine with trees for their shade-tolerance. More extensive information can be found in the database of edible plants of the Plants For A Future (PFAF 2004).

Brassica juncea (Mustard)
This is a very hardy vegetable from the Orient, where it is highly appreciated for its flavor. Various varieties grow well in our climate. It grows on most soils, if moist and well drained and preferably fertile. It grows well in sun and half-shade. The leaves can be cooked or eaten raw and can also be harvested in winter. The seed is used a mustard flavoring and various varieties exist of which also the root and stem can be eaten (PFAF 2004).
**Cryptotaenia japonica** (Japanese parsley, mitsuba)
This short-lived perennial grows to 1 metre tall when in flower and about 60cm wide. It succeeds in most soils, preferring a moist shady position under trees where it often self-sows. It may not be winter-hardy in all areas of the Netherlands. It is usually grown as an annual, though plants can tolerate short periods at temperatures down to about -10°C. Mitsuba is commonly cultivated as a vegetable in Japan (PFAF 2004). The leaves and stems can be eaten raw or cooked (shortly) and have a parsley-like flavour. The seedlings and young leaves can be used in salads whilst older leaves are used as a flavouring.

**Claytonia perfoliata** and **C. sibirica** (Miner’s lettuce and pink purslane)
These species are particularly suitable to grow in shade, even in dense shade, although they grow in sunlight as well. **C. sibirica** is a short lived perennial and **C. perfoliata** is an annual, but since they self sow freely, they can be used as a dense perennial ground cover, providing edible leaves year-round. They are very hardy and will grow on most soils, even nutrient poor soils, but **C. sibirica** requires moist humus rich soils for best results (Fern 2000, PFAF 2004).
Both are easy and very productive salad plants of which both leaves and flowers are edible, raw or cooked.

**Allium ursinum** (Wild garlic, daslook)
This is a native protected species that can grow prolifically in woodlands, often forming large colonies. It prefers a moist well-drained and calcium rich soil and is often found in the wild growing in quite wet situations. Plants come into growth in January or February, they flower in the spring and have completely disappeared by mid summer, thus allowing other plants to grow in the same space during the summer.
The leaves, coming as they do in late winter, are a very welcome addition to our salads and cooked foods. They have a moderately strong garlic flavour, though this reduces as the leaves get older. The flowers have a slightly stronger flavour and make a very attractive addition to salads whilst the small bulbs can be used just like garlic (Fern 2000, PFAF 2004).
Since they are very attractive they can also be marketed as an ornamental garden plant.

**Asarum canadense** (Snakeroot, mansoor)
This plant grows about 10cm tall but spreads slowly to form clumps 50 cm or more across, making a good ground cover. It prefers a rich moist neutral to acid soil though it is also found on alkaline soils in the wild.
The underground stem and the flowers are used as a ginger substitute. The root has a pungent, aromatic smell like mild pepper and ginger mixed, but more strongly aromatic. It is best harvested in autumn but is available all year round and can be dried for later use (Fern 2000, PFAF 2004).

### 5.4.5 Gourmet mushrooms
Gourmet mushrooms are commonly grown in American forest farming systems (Hill and Buck). Best known and of most interest for (agro)forest owners is the shiitake mushroom (*Lentinula edodes*), which is cultivated on small 10-20 cm diameter hardwood stems (e.g. beech, maple and, preferably, oak logs), which may be the products of thinnings (Hill and Buck 2000). Using this roundwood for the production of gourmet mushrooms may be especially cost-effective for owners of small woodlots or agroforests, with unmarketable amounts of thinnings. It should be considered that the harvesting of mushrooms is rather time consuming and that the market demand for these expensive mushrooms is thin.

Inoculated logs take 6 to 12 months to produce the first mushrooms, depending on the strain of spawn used, species and size of logs and the macro- and microclimate. Logs can produce for 5 years and may be soaked repeatedly to force fruiting. Logs are estimated to produce at
least 100 g of shiitake per kg of wood during a five year production cycle (Hill and Buck 2000).

In addition to shiitake, oyster (Pleurotus sp.) maitake (Grifula frondosa), reishi (Ganoderma lucidum) and linon’s mane (Hericium erinaceus) depend on the digestion of wood fiber and may be considered for cultivation in agroforestry systems (Hill and Buck 2000). These can all be produced in a similar manner. Another option may be to cultivate shiitake or oyster mushrooms on tree stumps. In France and Hungary poplar stumps are cleaned up in this way, saving the money of mechanical removal (Oosterbaan and Valk 2000).

5.4.6 Apiculture
Agroforestry systems are very suitable for apiculture, the care and management of honeybees for various products and/or for pollinating agronomic or tree crops. Hives can be introduced in existing forest systems (i.e. forest farming), or new plantings could be designed to favor bee forage (Hill and Buck 2000, Hill 1998). Fruit trees require bee pollination for effective fruit set. Other trees, as black locust (Robinia pseudoacacia), chestnut (Castanea sativa) and Tilia spp. are known to have flowers that produce nectar and pollen attractive to bees and can produce high quality honey (Hill and Buck 2000). If managing a forested area in part for bee forage is desirable, it may be important to thin the existing trees enough to expose more of the trees’ crowns to sunlight as exposed tree crowns provide a greater surface area in relation to the volume of the crown to produce flowering bee forage (Hill and Buck 2000). This again may give opportunities to grow other products under the tree crowns. In silvopastoral and silvoarable agroforestry, planting bee forage in the tree line may favor honey production and provide additional income. Apart from honey, apiculture can produce valuable products as beeswax, propolis, royal jelly, bee venom (for therapeutic uses) and bee pollen.

5.5 Crops for fiber and bio-energy production

During the last decades, the Dutch government has been stimulating farmers to take arable land out of production to decrease overproduction. One example of this is the planting grant for fast growing trees (poplar) on arable land. This planting grant however, is not given for intercropped poplar, because this would still mean a contribution to the overproduction (Edelenbosch 1994). Nevertheless, agroforestry could contribute to the decrease of overproduction, especially when choosing non-food intercrops, as the production of bio-energy or fibers.
Moreover, production of fibers and of biomass for bio-energy have been proposed as promising alternatives for the production of conventional agricultural products, of which revenues are ever-decreasing. The market for fibers and bio-energy is supposed to rise in the near future, making the production of crops which yield such commodities interesting for farmers.

A variety of crops for fiber and bio-energy have been investigated in recent years. In this report, the stress is put on two very promising crops, namely hemp for fiber-production and short-rotation coppice for bio-energy. Both have interesting qualities as intercrops in agroforestry systems.

5.5.1 Hemp
Hemp (Cannabis sp.) could probably be a very good intercrop for the first years of tree establishment. Various researchers (Edelenbosch 1994, Garrett and McGraw 2000), suggest hemp as an excellent intercrop species, among others for its good market-perspective. Hemp
grows well under the Dutch climatic conditions and thrives on all soils except very poor sands such as the Veluwe. Hemp would grow best on fertile soils, such as the northern and southwestern sea clay areas and in the “Hollandsepolders” and “Ysselmeerpolders”. De “Veenkoloniën” are moderately suitable for the cultivation of hemp (van Soesbergen en van Lanen 1992).

At present, narrow cropping plans, overproduction and decreasing prices of conventional agricultural products are major problems in Dutch agriculture. Hemp could add to the cropping cycle (and thereby decrease the problems with soil bound pests and diseases) and decrease the production of conventional crops and the use of agrochemicals. Hemp has the habit to quickly cover the soil surface and outcompete weeds. Furthermore, most literature reports that hemp suffers from few pests and diseases. Van der Werf et al. (1994), however, found that in wet years hemp can suffer severe damage from fungi in the Netherlands, especially of Botrytis cinera. Fungicide applications did not increase stem yield. Therefore, there is no reason to use pesticides in hemp: herbicides are superfluous, fungicides have not found to be effective and other biocides are not needed. The plant requires relatively little fertilizer in comparison to other fiber crops and additionally it has the ability to clean contaminated soil (Robinson 1996). Kok et al. (1993) investigated the effect of fiber hemp on three major soil pathogens: the fungus Verticilium dahliae and the root-knot nematodes Meloidogyne chitwoodi and Meloidogyne hapla. All three pathogens were suppressed by hemp, indicating that the introduction of hemp in a crop rotation might improve soil health.

Van der Zwan (1982) suggests that hemp could be a good addition to the usual rotation of potatoes and sugarbeets/cereals in the Veenkolonien. Intensive cultivation of starch potatoes in this area has led to declining soil quality (low organic matter and sensitivity to wind erosion) and an increased disease pressure. This has resulted in decreasing yields and increasing costs of spraying, making it harder and harder for farmers to survive. According to van der Zwan, hemp would probably be an economically viable alternative crop. If sown in high densities, self-thinning of hemp automatically means that organic matter is added to the soil. This, combined with its abilities to control the growth of weeds, and probably also that of wild shoots of potatoes and sugarbeets, makes hemp especially interesting for the Veenkoloniën.

Also van der Werf (1994) concludes that fiber hemp has a high potential as a “new” crop in Dutch agriculture: “growing hemp may be economically worthwhile for Dutch farmers, hemp stems potentially have a large non food market, and the crop requires little or no biocide and suppresses weeds and some major soil-borne diseases”.

Hemp is usually sown at high densities, leading to intra-specific light competition and thus increasing length growth and self thinning from canopy closure. This stem elongation is a so called shade-avoidance strategy (Terhurne 2001). Increased length growth is preferable, because it leads to more of the valuable product, the fibers. Possibly hemp would show the shade-avoidance strategy in a similar way in agroforestry, which would mean that less seeds per hectare are needed to attain stem elongation. Since hemp grows quite high (up to about 3 - 5 m), inter-specific light competition between the hemp and young trees would force both crops into length growth. As in high-density plantation forests, the trees would form straighter and longer logs with less intensive pruning. Nair (1993) describes a similar old Chinese agroforestry system, whereby seedlings of Sophora japonica was grown together with Hibiscus sp. to obtain vertical and uniform tree seedlings for planting along roadsides. A disadvantage of high crops is the decreased ventilation of the tree canopy, which may increase the impact of diseases on its foliage (Dupraz and Newman 1997).

Almost every part of the hemp plant can be used by industry: the grain like seed, the strong fiber and the woody core. Hemp fibers are used for many things, amongst others for the production of textiles and paper (for extensive information, see Brown 1998, Robinson 1996).
Since hemp has the ability to produce up to 4 times more fiber per hectare than trees do, it is a perfect alternative for the production of paper pulp (Robinson 1996, van der Zwan 1982). The stalks and seeds can be used as an energy source. Since hemp is harvested yearly, it may be a more interesting option for farmers to grow hemp than to invest in long term poplar plantations for pulp production. Experiment of Terhurne (2001) in Italy even showed that the best quality hemp can be harvested at 400°C days, giving this “baby hemp” a different place in the cropping system, which makes it more attractive. It can then be grown as a second crop after an early crop such as seed potato, or two consecutive hemp crops can be grown.

Despite the many advantages of hemp, it is only recently that various western countries rediscovered the values of hemp and starting to cultivate again after decades of legal suppression. It is still a rather unfamiliar crop and most hemp markets are still in their infancy. According to Robinson (1996) industrial countries will need to invest in the design of new farm machinery before large scale plantings will be cost-efficient. Bakker and Van Kemenade (1993) though, conclude that fiber hemp for pulp is potentially a profitable crop for arable farmers in the Netherlands, if a pulp factory is set up. Also de Meijer (1993) noted that the main factors for a successful introduction of hemp as a pulp source are not botanical or agricultural, but industrial and political considerations. However, more than twenty companies in Europe alone are engaged in the primary processing of hemp, of which several in the Netherlands. Demands in 2001 were higher than the supply, due to the increasing establishment of hemp as an industrial fiber and the simultaneously decreasing EU subsidies. Karus (2002) mentions that in 2002 the seven main companies intended to considerably increase their combined contract area to more than 14,000 ha (+40%). He remarks that, it is questionable whether enough farmers can be found to grow hemp under the current (and future) economic conditions.

In Canada, enzyme technology processes are being developed that reportedly may have hemp fibers replace cotton worldwide (Hemptown 2004). Such developments could make the cultivation of hemp even more attractive.

5.5.2 Short-rotation coppice for bio-energy

All over the world researchers are looking for sustainable alternatives for fossil fuels. Apart from the growing concerns about the exhaustion of these finite resources, more recently the concerns about human-induced climatic changes have led to numerous investigations on sustainable solutions. One of the alternatives receiving much attention, is that of bio-energy crops. The European union and the Dutch government have pledged enormous support to turn the current vision of sustainable energy production into reality. The Dutch government has proposed a target share of 10% of the national energy demand to be fulfilled by renewable resources by the year 2020 (and 5% in 2010). Twenty-five per cent of this renewable energy must be produced using biomass (Brinkhorst 2000). This is more than seven times the yearly yield of wood-thinnings in the Netherlands (Kuiper en Jansen 2002).

Sweden and Britain lead the science and technology for biomass production in temperate climates. In the last 20 years enormous research and development have been done in this area, particularly that relating to willow and poplar trees grown as arable crops using agroforestry techniques and more popularly known as short-rotation coppicing (SRC). Straw, peat, forest residues and energy coppice are already providing some 15 percent of Sweden’s total energy requirements. Also in the UK and the USA there are numerous examples of heat and electricity production from wood, often by independently owned biomass power plants (Macphersons 1995).

Short rotation coppice reportedly gives farmers the opportunity to use government and EU assisatance in a constructive and productive way rather than simply leaving land under unsightly set-asde (Macphersons 1995, SBH 1994). However, long-term contracts are
suggested to guarantee farmers of a market for SRC (SBH 1994). Farmers could sell their
products to produce heat or electricity, or both. Potential non-energy markets for SRC may
be chipboard factories, the pulp- and paper industry and the charcoal market (Macphersons
1995). Another option may be to produce heat and/or energy on a small scale for on farm use, e.g. for horticultural uses or heating and lighting the homestead (Macphersons 1995, SBH 1994). Tholhuijsen (1986) calculated that half a hectare of poplar can yield enough firewood to replace 3000 m³ of gas. On this small scale, with little mechanisation and home-use of the energy, the system would give a revenue equalling that of maize.

According to Macpherson (1995), the advantage of SRC above other alternative arable
crops, which often require the finding or creation of niche markets, is that the potential
market is healthy and growing. SRC, for now, offers everything that the farmer could want;
low labour, high production, low fertilizer or chemical requirements, large acreage, use of
existing machinery (standard arable implements for seedbed preparation and almost
standard forage harvesting gear for coppice harvesting), environmental enhancement and a
high potential for public acceptance. The main question is if the farmer could sell it for a good
price, i.e. is it profitable?

In the Netherlands, currently only residues are traded for bioenergy on a commercial basis to
feed several power plants in the Netherlands. Prices for forestry residues, (clean) waste
wood and other biomass types of comparable quality, vary between € 0 and € 25 per oven-
dry ton (odt) before transport, which are assumed to be competitive with fossil fuels such as
coal (Londo 2002). Londo (2002) calculated that willow biomass production in single-land
use energy cropping on agricultural land can never compete with this price. The low value of
biomass means that dedicated energy crops can not compete with common agricultural
crops and the introduction of energy farming as single land use will hardly have a chance.
Furthermore, on the long term the availability of land in the Netherlands is too limited to cover
the expected future need for the production of energy crops.

Multiple land use is suggested as a solution to improve the financial competitiveness of
energy crops and to tackle the problem of future land scarcity (Londo 2002, Windt et al.
2001). As an option to reduce break-even prices and hence make prices of willow coppice
competitive with those of residues, Londo (2002) proposes to avoid competition for land with
common agriculture, but to seek for land dedicated to e.g. nature conservation and
recreation. An additional advantage in this respect is the possibility to grow willow without or
with low fertilizer and biocide application, making it attractive in groundwater protection
areas, groundwater extraction areas and as a habitat for a range of animals, e.g. breeding
birds. Through some of these applications indeed a significant competitiveness increase can
be obtained. However, Londo (2002) predicts that the price reductions are not in the order of
magnitude that the price of energy crops draws near to the current prices of biomass
residues.

Although, according to Londo (2002) perspectives for willow short rotation coppice may be
limited on the short term, this could well change in the future by technical innovations in
energy cropping, leading to more competitive supply prices through decreased cultivation
costs and increased productivity. Furthermore future changes in the current market
regulations and supportive payments to farmers may make energy crops more competitive.
For instance the introduction of multiple land use energy farming on fallow land under the EU
set-aside scheme could be an option. More governmental incentives to the development of
energy crops, as in Sweden and the UK (Macphersons 1995), could be another option.
Finally, if climate change concerns lead to increasing demands for bioenergy, or to a pricing
system of CO2 emissions, energy cropping may benefit, especially when the amounts of
available residues are not sufficient to meet demands. Hence the development of SRC for
biomass production are greatly dependent on decisions at the international level. Windt et al.
(2001) however, conclude that the reasons that the large-scale cultivation of biomass is not running so fast, are for the major part a lack of awareness or a lack of clarity and the difficulty to get the various actors together and on one line.

Within the concept of multiple land use, also the cultivation of short rotation coppice as intercrops (i.e. intertrees) in the alleys between standards of valuable tree species for log production can be an option. Such management systems will thus include only trees and consequently are not agroforestry systems in the strict sense (see Paragraph 1.4). They are essentially similar to two-strata forest ecosystems. Dupraz and Newman (1997) mention that new agroforestry systems are now designed with alleys of coppice between lines of hardwood trees. On wet land willow SRC may well combine with red or black elder standards for veneer production. On drier grounds standards of poplar, ash, maple, wild cherry or walnut for log production may be an option. Since no such examples are reported in the Netherlands, such combinations may require further exploration to determine their viability.

5.6 Conclusions

Until now, agroforestry research in temperate Europe has mainly focused on the integration of conventional, intercrops and trees. Although in principle any crop can be grown, most promising seem to be rowcrops as maize and cereals, grass, leafy vegetables and particularly wintercrops. The conventional crops are rather light demanding, and in agroforestry their production may be highly reduced due to sub-optimal light conditions under large trees. At this point often replacement of the light demanding crop by shade-tolerant forages (grass, clover), reducing the intercrop width or leaving the alleys bare are the recommended alternatives. It is questionable, however, if these are the most sustainable options, both in terms of economy as ecology. There is a broad range of interesting alternatives, which can produce valuable products in the (shaded) alleys, both on a large scale for the bulk market and on a smaller scale for certain niche markets.

Some innovative alternatives, like free range poultry, small fruits, short rotation coppice and certain ornamental and medicinal plants have a great potential for large scale production on intensive mechanized farms. Others, such as production of “wild” meat, specialty vegetables, gourmet mushrooms, certain small fruits and herbs and fragile ornamentals may be of interest for more extensive land users and can yield a variety of valuable products for various niche-markets.

Agroforesters actually have the choice of a multitude of intercrop options, many of which need further investigation before application. Special interest deserve the cultivation of shade-tolerant small-fruit, gourmet mushrooms and high-value medicinals as ginseng and the cultivation of non food crops for fiber and biomass production, as well as the production of free range poultry and “wild” meat in agroforestry systems. As with trees, the optimal choice of species will depend on the specific situation regarding ecological, technical and economic aspects as well as farmers objectives. The appropriate tree-crop combination and the system design are crucial in terms of reducing competition and hence optimizing the land equivalent ratio (LER). The interdependence of the various factors and suggestion for Dutch agroforestry practices are elaborated in Chapter 8.
6. Governmental regulations and subsidies with (possible) relevance to agroforestry

Although subsidies and regulations are subject to regular changes, the following gives some insight in the current regulations and grants, which may be of use and of importance for agroforestry. For up to date information it is useful to check the website of the ministry of LNV (LNV-loket 2004).

6.1 Restrictive regulations

Through the re-allotment and the increasing efficiency of Dutch agriculture, many farm-forests and solitary trees have disappeared from the rural landscape. To prevent a further erosion of trees from the Dutch countryside and to increase the production of wood in the Netherlands, the Dutch government implemented a regulation to oblige landowners to announce the felling of trees on their land and to replant trees after felling (regeling meldings-en herplantplicht). This implies that an arable plot with trees may obtain the status of forest, which means that the plot will fall under the forest law and considerably decrease in value.

This regulation is very important to consider when planting trees. For temporary tree plantings however, it is possible to ask ‘exemption of the replant-obligation’ (ontheffing van de herplantplicht), which was introduced to promote the establishment of plantations of fast-growing trees on farms. The exemption however, is currently only permitted if the trees are felled within 40 years. If these regulations are maintained in the future, this means that landowners who do not ask for ‘redemption’ or maintain their trees for a longer stretch of time, have a chance to be obliged to plant new trees after felling and see their land shifting to a forest status (i.e. decrease in value).

Besides these regulations, which fall under the Dutch forest law, one should also take into account regulations on the municipal and regional level, when considering the establishment and felling of trees.

6.2 Grants on tree planting and/or maintenance

In the Netherlands various subsidies are available to maintain elements of ecological or cultural value. These subsidies fall under the ‘subsidy agrarian nature-management’ (subsidie agrarisch natuurbeheer, SAN). Several of these are directly aiming at specific forms of AF, others may have relevance for alternative agroforestry systems. Usually the subsidies are given if the management-unit is maintained according to the rules for 6 years, after which the contract may be extended with another 6 years and so on. Sometimes also establishment subsidies are available. In this paragraph the conditions of these arrangements and the current height of the subsidies are described.

It must be noted however, that it always depends on the province if subsidies are provided:

- the element should fit within the conditions of the provincial area-plan, which decides which kinds of nature should be developed and maintained in which area. The only exception to this rule is fast growing forest, which does not have to fall within the boundaries of the area-plan to receive subsidies

- every province has hectare-quota on their subsidies. If the quota for a package is full, no more subsidies can be given on that package
This chapter is only aiming at giving suggestions on the interpretation of the subsidy regulations, which may favor the application of agroforestry within these subsidy-systems. Apart from the subsidy on high-stem orchards, mentioned hereafter under point 1, the other subsidized systems are aimed at short rotations or copse wood. Although the inclusion of valuable trees for a longer term seems possible considering the rules on paper, this should be reconfirmed in practice. For more extensive and up to date information on subsidies and regulations, referred is to LNV-Loket (2004) and Steunpunt Hoogstamfruit (2004).

1. High-stem fruit/nut orchards (landscape package 60, package-code 3600)

Recently the Dutch government is stimulating the planting and maintenance of high-stem fruit trees to bring back the traditional high-stem orchard in the cultural landscape. Via the ‘subsidy agrarian nature-management’ (subsidie agrarisch natuurbeheer, SAN) or the ‘fund for renovation of the countryside’ (fonds vernieuwing landelijk gebied) it is possible to receive subsidies on the establishment or renovation of high-stem orchards of more than 15 trees.

If more than 0.25 ha is planted it is also possible to receive a yearly management subsidy of € 14,89 (2004) for each tree, if the system is according to the following conditions:
- orchards may consist of walnut-, apple-, pear-, plum or cherry trees
- the trees must measure over 4 m when mature
- densities must be over 50 and under 150 trees/ha
- management should only be aimed at maintaining the cultural element. Apple and pear must be pruned at least every two years. The orchard must be yearly mown or grazed
- no chemicals and artificial fertilizers should be used in or near (<1 m) the element

2. Fast growing (temporary) forest

a) Fast growing (temporary) deciduous forest (management package 31, package-code 3310)

Conditions:
- at least 90 % (crown-projection) of the area consists of forest
- at least 80 % of the area is occupied with the following species:
  - eur-american poplar
  - schietwilg
  - west-amerikaanse balsempopulier
  - zwarte balsempopulier
  - zwarte populier
  - a minimum of 400 trees/ha
  - a minimum area of 5 ha

b) Fast growing (temporary) pine forest (management package 32, package-code 3320)

Conditions:
- Similar as under a), but with a minimum of 2500 trees per ha and the following species:
  - Corsicaanse den
  - Douglas
  - Fijnspar
  - Sitkaspar
  - the trees are not to be used as christmas trees
Both receive a subsidy of E545,-/ha/y (2004) in three terms of 6 years, so 18 years in total. On forehand an 'exemption of the replant-obligation' must be submitted, to prevent the plot of falling under forest law, which includes the obligation to replant forest after felling (see Section 6.1). On this package also an establishment -subsidy is available. Herefore a set-up plan must be made and approved upon.

These regulations would theoretically permit a 20 % cover with other, more valuable and long term species. It remains unclear however, if the whole plot should be harvested within a short rotation to obtain the subsidies, or if it would be possible to maintain certain trees for a longer term.

3. Tree row or hague (landscape package 65, package-code 3651)

Conditions:
- it is a linear element, covered at least 90 % (crown-projection) with indigenous shrubs and trees
- it is at least 50 m long and maximum 20 m wide
- it consists of copse wood, but may contain not coppiced trees
- management should only be aimed at maintaining the cultural element
- management measures should only take place between september 1 and april 1
- no chemicals and artificial fertilizers should be used in or near (<1 m) the element

In theory the not coppiced trees could form a valuable and long term tree component, while the copse wood could act as an intercrop, e.g. for biomass production.

This system would receive a subsidy (2004) depending on the crown-projection:
E657,61/ha/y for a cover higher than 90%
E493,21 /ha/y for a cover between 75 and 90%
E328,81/ha/y for a cover between 50 and 75 %

4. Borders of elders (elzensingel) (landscape package 54, package-code 3541)

Conditions:
- subsidies are given on the maintenace of continuous strips of native greens, which consist for 80 % of black alder
- the strips are minimally 50 m long, consist of copse wood and contain a maximum of 3 trees per 100 m, which are not coppiced (overstaanders)
- the other trees should only be 0.15 m diameter (at 1.30 m above the trunk), or 0.25 m in sandy areas
- management should only be aimed at maintaining the cultural element. This means regular pruning at 0.1-0.3 m height
- management measures should only take place between september 1 and april 1
- no chemicals and artificial fertilizers should be used in or near (<1 m) the element

This system would receive a yearly subsidy (2004) of depending on the crown-projection:
E29,89 per 100 m for a cover (crown-projection) higher than 90%
E22,42 per 100 m for a cover between 75 and 90%
E14,95 per 100 m for a cover between 50 and 75 %

Hence this arrangement would permit the inclusion and maintenance of valuable native trees for logproduction at low densities (max. 3 per 100 m length) and hence create possibilities for extensive agroforestry systems.
5. Farmer's copse wood forest (geriefhoutbosje) (landscape package 55, package-code 3550)

Conditions:
- the area should be between 0.05 and 0.5 ha and contain at least 5000 stems of indigenous trees per ha. The element should consist of copse wood, of which a maximum of 500 are not coppiced (overstaanders)
- management should only be aimed at maintaining the cultural element. This means regular coppicing at maximum 50 cm above ground or just above the trunk if it is higher
- management measures should only take place between september 1 and april 1
- no chemicals and artificial fertilizers should be used in or near (<1 m) the element

This system would receive a subsidy of E597,83,-/ha/y (2004). This arrangement may create possibilities of small scale agroforestry with valuable indigenous trees (e.g. chestnut) and copse wood as an intercrop.
7. The reaction of Dutch farmers to new silvoarable and silvopastoral systems

Executive summary of the attached report

7.1 Introduction

At present, knowledge on agroforestry in general is quite poor in the Netherlands as in most other European countries. This is due to the marked decline in agroforestry systems across Western Europe throughout the last century. In the Netherlands, with the exception of windbreaks and riparian buffers, agroforestry plays currently no role. Re-introduction of such systems requires first of all an information exchange between potential agroforesters and institutions with interest in agroforestry. In this context, the SAFE-project developed and performed a survey in 7 European countries, i.e. France, Spain, UK, Germany, Greece, Italy and the Netherlands. This chapter provides an executive summary of the survey results in the Netherlands. The complete paper is attached to this report. The methodology and the aims were the same for each country.

7.2 Objective and methodology

The principal aim was to explore the interest of Dutch farmers and estate owners in agroforestry and to determine the conditions of acceptability of new agroforestry systems.

The survey consisted of three steps. First respondents were asked whether they knew agroforestry and what it was, followed by information on agroforestry by means of a PowerPoint presentation. Then technical questions on the design and implementation of a virtual agroforestry project were asked. Finally the respondents were asked to evaluate agroforestry, which issues they expected to constrain the adoption agroforestry and how these issues could be solved.

In January 2004, the questionnaires were held under 27 farmers and 2 estate owners in two rather different regions in the Netherlands, namely the Achterhoek and North-Friesland. Within each region farmers were randomly selected from a list, which was purchased from AgriDirect in Dronten, a specialist in Agrimarketing. Two estate owners were randomly selected from a list of estate owners in the Achterhoek, that was obtained through GPG (Landowners Organization of the province of Gelderland, of which the Achterhoek is part).

7.3 Research area

The Achterhoek is located on sandy soils in the East of the Netherlands. The region is traditionally characterized by mixed farming, relatively small farm and plot size and many woody landscape elements. Trees are abundant. The many estates contribute for a major part to the cultural-historical and natural values of the area.

Northern Friesland, is located on the clay-soils in the North of the country and is characterized by large farm and plot size (compared to those of the Achterhoek) with more
specialized and intensive land use. The landscape is traditionally very open. Plots are often separated by ditches and hardly any trees or bushes are found in or around arable fields.

7.4 Results

For both the Achterhoek and N-Friesland the concept of agroforestry as being “wide-spaced trees intercropped with arable crops” (SAFE 2004), is new. None of the respondents has seen or heard of agroforestry as such. Since most farmers have rather experienced the negative aspects of trees for the farm economy, farmers tend to be sceptical about the feasibility of agroforestry in their situation. Although farmers were interested in the concept, in general farmers saw better options for agroforestry in areas where plots are larger and agriculture and the accompanying pressure on land are less intensive, such as the marginal areas in the northeast of the Netherlands, France or Eastern Europe. For the majority of the respondents it holds that if the system brings in enough money, they are interested to apply it on their farm. But farmers see more opportunities for hobby-farmers or stopping farmers, who are not financially dependent on their agroforestry plots.

In the Achterhoek, many fields are bordered by tree lines or bushes and thus farmers are more used to trees, their effects on crops and the work for tree maintenance. That may be the reason that farmers in the Achterhoek are more open to agroforestry than farmers in the open Friesian landscape. Friesian farmers think trees do not belong in the open landscape, that they will increase pest pressures on the crops and have an adverse effect on the traveling birds.

Farmers in both regions see a lot of negative aspects of agroforestry (Figure 7.1), mostly of a technical matter: problems with mechanization, labor, shade and related to those decreased revenues on the intercrop.

Consequently, various environmental values as landscape value are considered the major positive aspects of agroforestry (Figure 7.2). Landscape value is also the major reason to maintain trees on the farm, apart from the fact that farmers are forced by law to maintain trees (Paragraph 6.1).

Most farmers emphasize the need for subsidies to compensate for the losses on the revenue of the intercrop and the expected extra costs for labour and tree maintenance. On the other
hand, many farmers underline that government subsidies and regulations are subject to change and hence a risk factor. Clear and long-term subsidies and regulations can be considered a primary prerequisite for the successful introduction of agroforestry in the Netherlands.

Another constraining factor is the lack of knowledge on the management of the trees, the returns of wood and the wood-market. Since most farmers have the experience to gain little or no money by the sale of wood, they have little confidence in the profitability of agroforestry. Clear calculations of the returns of agroforestry in the Dutch situation are necessary to convince farmers of its feasibility.

Figure 7.2, Positive aspects of agroforestry named first in both regions (t=29)

Especially farmers in the Achterhoek were open to the idea of managing the intercrop if their neighbour would start agroforestry (Figure 7.3). Farmers were a bit more reluctant in accepting the intercropping area, if their landlord would start an agroforestry project on the land they were renting. The interest of estate owners for such co-operation needs further investigation.

Friesian farmers were more conservative in cooperation with neighbors and landlords, which may be explained by the fact that they are less dependent on landlords compared to the farmers in the Achterhoek.

Figure 7.3, Willingness to accept an intercropping area from a neighbour (n=27)
Proposed was furthermore to explore the possibilities to let other parties, such as nature organizations or enterprises, take the care, risk and profits of the tree component and let the farmer manage the intercrop area. Another option to give farmers more security may be to let government or enterprises guarantee a certain wood price on stem.

Since farmers have little or no experience with tree production in general and agroforestry in particular, they find it hard to decide how they would design and manage an agroforestry system. Farmers pointed out to need much more background information and practical examples to make reasonable decisions on this. Nevertheless, most farmers predicted that they would choose large distances (20-25) between the tree rows to make for a good and healthy intercrop. Distances would be adjusted to the width of the machinery. Distances within the tree row will not affect the machinery and can thus be taken shorter to still come to a good wood production. Farmers in the Achterhoek were more willing to do the operations and the tree maintenance themselves than Friesian farmers. This may be explained by the fact that they already have to cope with trees on (the borders of) their farm and as such they often know about the tree maintenance.

Respondents found it hard to choose tree species for agroforestry. Favorite were fruit trees and poplar, as these give early benefits. Grass, cereals and maize were considered the best conventional intercrop (Figure 7.4), although most farmers doubt whether the intercrop will not suffer too much from shade and humidity (problems with drying/ripening). A grass-cover is also the most popular option for soil maintenance of the tree strip and as land use option when annual intercrops become unprofitable. Various alternative and possibly shade tolerant intercrops were proposed.

**Figure 7.4, Best intercrop according to farmers in the Achterhoek (t=14) and N-Friesland (t=15)**

62% of the respondents in the Achterhoek said they would like to try an agroforestry project. Only 27% of the Friesian farmers were enthusiastic to try an agroforestry project. Whether respondents would adopt agroforestry would not so much depend on respondents’ age, but rather on profitability, the subsidies and on the (availability of a) successor.

### 7.5 Conclusions

Comparing the two regions, it can be concluded that the circumstances for the development of agroforestry are better in The Achterhoek. Farmers are more positive about the concept and seem more interested to try an agroforestry project. Furthermore they already have
experience with trees and are more open to co-operation with neighbors and landlords. The decreasing farm profits on the sandy grounds in the Achterhoek, increasing regulations and the limits to further intensification seem to force farmers to take a broader view on agriculture. The same may hold for other marginal areas in the Netherlands. Moreover, both the political and biophysical climate in the Achterhoek may be better for the introduction of agroforestry.
8. Synthesis and discussion: roadmap for adoption and design of new agroforestry systems

8.1 Introduction

The aim of this study is ‘to explore the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands’. Research and practice in other temperate regions suggest that agroforestry may have potential as a multiple land use system in the Netherlands. However, the way farmers and other land users make decisions and plans depends on many interacting variables (factors): what they aspire (objectives), what they believe to be true about the biophysical and social world (knowledge and insight), and what they (think they) are able and allowed to do (Leeuwis and van den Ban 2004). These variables shape a land user’s perception, which in turn will result in certain decisions and actions. As such, these variables can be helpful in understanding what farmers do and not do at a given point in time and can give us some entry points for supporting land users in trying new practices and eventually to adopt agroforestry.

The first limiting factor for the establishment of agroforestry, is that the majority of land users in the Netherlands have never heard of nor seen innovative agroforestry systems in the Netherlands. As such they miss the knowledge and experience to form a realistic picture of agroforestry (influencing their aspirations, beliefs, etc.) and they may feel incapable to become an agroforester (perceived ability). Secondly, and partly causing the previous, some major structural constraints discourage the establishment of agroforestry, e.g. a lack of research and extension service and the absence of a legal status of agroforestry. Furthermore technical, economic and social aspects may limit the adoption and realization of agroforestry.

The following paragraph sheds a light on these potentially limiting factors (constraints) and discusses ways to alleviate these constraints as well as general favourable conditions (opportunities) for agroforestry.

Agroforestry may have potential for distinctive groups of land users, such as farmers, foresters and small-scale/hobby farmers (depending on rural activities for a minor part of their income). The objectives, constraints and opportunities for agroforestry will probably differ for these three groups. This should be taken into account when designing agroforestry systems. Paragraph 8.3 focuses on the design of agroforestry systems and suggests (as an example) several different management practices for each group.

Finally, paragraph 8.4 will give conclusions on the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands.

8.2 Limiting factors and solutions for the adoption of AF

8.2.1 Lack of basic knowledge and skills

In the Netherlands, farmers and estate-owners appear to be unfamiliar with the concept of (modern) agroforestry and thus are not aware of its potential benefits. A major reason for this is the virtual absence of agroforestry examples in this country. Production efficiency and specialization are the order of the day. Many farmers have lost touch with the benefits of trees on arable land, like foresters have lost touch with the benefits of crops and grazing
animals in forests. What is more, in the eyes of many farmers trees are disturbing factors, that compete with their crops and hamper field work. This seems to be especially true for the 'polder-regions' or open landscape regions, where trees are virtually absent.

Through a lack of knowledge and agroforestry examples, farmers only have wild trees as a reference and only few are aware that certain species under agroforestry management can produce valuable products in less than 25 years. In a similar sense, Dutch foresters may believe that forests offer limited opportunities to plants, other than mosses and ferns. Their tradition is that forests are for producing timber and they may have limited awareness that forests can produce other valuable products as well.

The management of agroforestry is inherently more complex and demanding than that of monocultures and land users may not possess the necessary technical skills. For example, specialized arable or livestock farmers may not be familiar with many forestry techniques and vice-versa. Also the harvesting, processing and marketing of forest products may require new knowledge and tend to be more demanding than the production of agricultural commodities (Section 8.2.3).

Summarizing the above; to give agroforestry a chance in the Netherlands, first of all, land users must be made aware of agroforestry as a potential land use system. To convince land users of the benefits of AF, it will be necessary to provide precise information about possible (dis)advantages of specific AF systems (i.e. species and design) and management practices including calculations on financial investments, labour demands and returns. Even though several of the ecological advantages of agroforestry have been scientifically proven, as long as the economic advantages are not convincing, only few professional land users will be interested to initiate agroforestry.

Practical demonstrations of agroforestry in the Netherlands may be a good tool to change landowners’ perceptions of growing trees on their land and to show that agroforestry can be more profitable than monocultures. If a land user finally takes the step of implementing agroforestry, he should be able to receive information, training and advice on how to establish and manage this new land use type. The establishment of innovative agroforestry systems may thus be positively influenced through effective promotion, consisting of:

- awareness raising and information on the concept of agroforestry
- demonstration, training/education and information on the management of AF
- adequate advice and support in the establishment of new agroforestry systems

8.2.2 Structural constraints
As explained in Chapter 1, developments after the second world war targeted at separation of functions as forestry and agriculture. Since then, the related institutions have focused rather rigidly on the established disciplines and activities (i.e. forestry and agriculture), which hampers the establishment of agroforestry. The structural constraints include a lack of appropriate research and extension services, and discouraging government policies.

8.2.2.1 Research and extension
At present, the lack of a basis for effective promotion of agroforestry, namely an adequate research base and a network of researchers, teachers, extension workers and practitioners, constrains agroforestry development and adoption in the Netherlands. Newman and Gordon (1997) argue that, apart from the farmers’ perception, the perception of ‘land use specialists, extension agents and advisers’ (negatively) affects the development of agroforestry. This holds for the Netherlands as well.
Similarly to farmers, researchers and extension workers are usually specialized and lack the interdisciplinary approach that is required for agroforestry. Ten years ago, Nair (1993) indicated that ‘the reluctance of the academic community to encourage and reward interdisciplinary, applied research, and the lack of funds and infrastructure for conducting such research are major disincentives to scientists and laboratories interested in such fields’. Nowadays the scientific world seems to be more aware of the necessity of interdisciplinary applied research as a basis for sustainable land use in the future. Despite this, in Europe and the Netherlands there is still little attention (also in terms of funding) for agroforestry, which explains the lack of agroforestry research (Wiersum pers.comm. 2004, Forest and Nature Conservation Policy Group, Wageningen; Oosterbaan pers.comm. 2004, Alterra, Wageningen; Mayus pers.comm. 2004, Crop and Weed Ecology Group, Wageningen).

Similarly to the situation of specialized land use systems in the Netherlands, extension staff is usually specialized with respect to the common systems and lacks the skills and tools to address agroforestry issues. There will always be some innovative landowners, that will implement agroforestry anyhow and learn by trial and error. However, for the establishment of agroforestry at a large scale, finally a shift in the organizational structure of extension organizations towards multidisciplinary service is required.

### 8.2.2.2 Governmental policies

In the Netherlands, governmental policy is more and more aiming at an extensification of the current agricultural systems, leaving more room for nature and thus increasing biodiversity. Nowadays, farmers are subsidised for extensive pasture management or natural management of field borders to increase biodiversity. Former agricultural lands are “developed” into nature and millions of Euros are invested in the connection of natural areas by means of natural corridors, the so called “Ecological Main Structure”. Within this framework AF would fit perfectly, particularly as a gradual transition between natural areas and agriculture. Furthermore agroforestry systems could be an environmentally sound alternative to the over-production of food crops and produce valuable timber and biomass to fulfill the needs for bioenergy. Nevertheless, both the current grant-regulations and the law often discourage the establishment of innovative agroforestry systems.

**Subsidy system**

In most European countries, including the Netherlands, the integration of trees and arable agriculture is currently unattractive to farmers, because the available subsidy regulations are designed for either forestry or agriculture. A mixed or combined status for agroforestry plots is currently not available in the Netherlands (see also Section 3.3.2). This discourages AF, as (in most cases) agroforesters can neither receive the grants for forestry plantations, nor those for agricultural crops. Crop grants may be available, when the crop field has a minimum width of 20 m (Repelaer pers.comm. 2004, Hoenderloo).

Regarding the dependence of Dutch farmers and foresters on subsidies, adjustment of the subsidy system will be essential to give the establishment of agroforestry equal chances to that of agriculture and forestry. In this sense, also a change in perceptions among policy makers should be achieved; i.e. make the political arena aware of the potential benefits of agroforestry and the necessity to acknowledge agroforestry as a ‘legal’ form of land use and adjust regulations accordingly.

Besides, governmental support in the form of establishment grants and compensation payments for initial revenue losses should partially accommodate the risks and consequently greatly reduce the importance of investments as a constraining factor. Government support could accommodate the initial establishment of modern agroforestry systems in the Netherlands, which can serve as a test ground of agroforestry and fill the gap of empirical proof and practical demonstration in the Netherlands. This may support a further shift of land users towards agroforestry applications.

83
Nowadays, in several regions of the Netherlands, grants for tree planting are available and might be applicable to very specific AF designs (see Section 6.2). This implies that at present only those specific AF systems may be viable and attractive and only in certain regions. Grants on high-stem orchards for example, are only available in regions where these systems were traditionally found, e.g. in the Betuwe area. Moreover, these grants are usually bound to a maximum budget. For the widespread uptake of AF more grants and with a wider application should be made available.

To give agroforestry systems an equal chance to common agricultural and forestry systems, SAFE (2004) proposes an European “agroforestry status should be considered for the countries where tax policy and grant availability is dictated by land-use classes”, such as the Netherlands. Policies for agriculture and forestry grants should recognize that both silvoarable and silvopastoral systems are ‘legal’ forms of land use which should be permitted to be on a ‘level playing-field’ with conventional agriculture or forestry. On January 1 2005, a new Common Agricultural Policy will be enforced in the European Union. There is a chance that AF will be recognised and promoted by the new CAP, not at least due to the recent achievements in ‘agroforestry policy’ in France, the scientific efforts of the European project SAFE5 to identify the conditions under which agroforestry could be environment-friendly and economically profitable and the recommendations with respect to land use regulations given by a mixed group of European agroforesters (SAFE 2004).

Legal system
In the Netherlands, the legal system does not recognize agroforestry as a land use class. Consequently legal matters discourage the planting of trees on arable land. If trees are planted on arable land, the land usually is classified as forest, which means that the value of the land decreases. Landowners have to ask for permission for the felling of trees on their land and trees must be replanted after felling. A dispensation of the obligation to replant trees after felling can be provided by classifying the plantation as ‘temporary forest’ (LNV-loket 2004). However, the status ‘temporary forest’ has a maximum life time of 40 years, which limits the use of trees with a long life cycle. Since the municipal and regional authorities provide the dispensation, AF may have more potential in one municipality/region than in another. The recognition of AF as a ‘legal’ form of land use and the ‘definition’ of related regulations would probably make agroforestry, in particular the planting of trees with a long life cycle, attractive to farmers.

8.2.3 Other socio-economic factors

Investments and labor
The costs of establishment and maintenance of AF systems may be high and there may be a considerable time-lag before the system, particularly the tree compartment, gives good returns, leading to initial revenue losses. This may be especially a constraint for farmers, used to regular returns from their crops or animals. In a survey about agroforestry (Chapter 7), farmers indicated that they would give preference to fast growing species as poplar and to species that provide products in the short term such as fruits. This choice may be due to the fact that farmers are not acquainted with the possible benefits of slower growing hardwood species. It can be expected that soundly based information and agroforestry demonstration plots may stimulate land users to reconsider their attitude towards long term and risk management and may motivate them to set-up an agroforestry field.

5 Silvoarable Agroforestry For Europe (SAFE 2004)
Apparently (Chapter 7) subsidies on investments and maintenance will directly change a landowner’s perception of risk and make the implementation of agroforestry much easier. As an alternative to subsidies, in the survey it was proposed to reduce the risk of long term investments by means of agreements, that guarantee a minimum timber-price at the time of tree planting. The agroforester receives a fixed price per tree, independent of log volume, when the trees are felled after a certain agroforestry period. Government and private companies could play a role in the development of such agroforestry contracts, which, in view of the growing demands for quality timber and biomass, could benefit both parties and greatly stimulate agroforestry.

A further suggestion was to let companies plant, manage and harvest trees on farms in exchange for good compensations (i.e. tree value). This would lay the responsibility and the related risks of the tree compartment by the external agent. In such cases, the farmer needs neither new skills, nor additional labour or investment. It is uncertain how many farmers would really accept other people managing part of their land and whether satisfactory agreements can be reached.

Also the requirements for labour and the properties of the labour market can play a decisive role in the adoption and design of agroforestry. Apart from the necessity to invest time and effort in acquiring new labour skills, farmers have clearly expressed the fear that agroforestry systems would require more labor. Moreover, the reaction of contract-laborers to the work in agroforestry situations may be of importance and requires further research. Land users' perceptions and, hence, the adoption of agroforestry would be positively influenced, if it could be shown that certain types of agroforestry require less labour and/or that labour is more spread and required in otherwise quiet periods.

An opportunity to reduce labour demands of the tree component may be to plant (coniferous) ‘nurse’ trees along the tree lines or high growing intercrops to train straight crop trees and hence minimize the time needed for pruning. Furthermore the ‘nurse’ trees may also reduce the establishment of weeds in the tree strips and help in reducing wind speed. Planting of Christmas trees as nurse trees could be done mechanically, otherwise the initial planting of nurse trees will require more labor.

Markets
The success of agroforestry may depend on the development of new markets or the expansion of existing ones and effective marketing by the agroforester. This holds for both the wood products and the secondary tree products and innovative intercrops. Most farmers will have no knowledge of the marketing of wood products and what is more, they may be disadvantaged by the small scale of the operation. Also the cultivation and marketing of other crops than the conventional agricultural crops in most cases will be new. In a similar way, foresters may not be used to the marketing of agricultural or secondary forest products.

The relevance of this issue will vary among landowners and among agroforestry systems. The type of AF and its type of products should match the agroforester’s interests/objectives and ideally fit the farm scale. Intensive farmers may not want to invest in marketing skills and thus prefer to cultivate conventional crops as intercrops. Innovative and/or smaller farmers may be more open to development and marketing of products and hence to innovative AF systems with alternative intercrops. Ecological farmers may have the advantage that certain innovative agroforestry products could be sold easily within the alternative circuit. Local or regional market features can play a role as well. Agroforesters near cities or in tourist areas for instance, may have more options for marketing agroforestry products or obtain benefits from recreation. In this sense, the regional location could to a certain extent determine the market feasibility and thus the potential of agroforestry.
Cooperation among farmers and between farmers and foresters may lead to more effective marketing, increasing the viability of agroforestry. To promote agroforestry on a big scale and to open up markets, it may be an idea to make consumers aware of the environmental advantages of agroforestry above conservative agriculture and to introduce a special agroforestry trademark, comparable to the ones that exist for ecological and free-range products.

For the establishment and maintenance of agroforestry, future agroforesters will also be dependent on what markets can offer with regard to planting material and equipment. If, for example, good planting stock or (reasonably priced) picking machines for walnuts and chestnuts are not available, this could mean serious limitations to the adoption of silvopastoral systems with these trees.

Cultural factors
The survey suggests that farmers in ‘tree-rich’ regions and farmers from regions with rather open landscapes, may perceive trees differently. Farmers in traditionally open landscapes may perceive trees as ‘polluting’ the view and reducing its landscape value, whereas farmers in ‘tree-rich’ regions are often used to cope with trees on their farms and feel more sure about skills related to tree-management. For the latter, trees are of cultural-historical significance and have a landscape value. This indicates that the local cultural background and environment may greatly influence land user’s perceptions on agroforestry as a potential land use system. It could imply that the adoption of AF may be more easy in ‘tree-rich’ regions.

8.2.3 Practical limitations
Even if the major aforementioned socio-economic problems are solved, practical issues, i.e. biophysical factors and technical aspects, can limit (certain) agroforestry applications in certain situations and hence will determine both the adoption and design of agroforestry system.

Biophysical factors
In the previous paragraphs it was described that certain regional features, e.g. cultural traditions, local regulations or markets, may influence farmers perception and hence the potential of agroforestry. More directly regional biophysical characteristics may affect the potential adoption of agroforestry, and the options for inclusion of plant and tree species in agroforestry systems.

The prevailing soil quality may affect farmers’ interest in agroforestry as an alternative land use system. In regions with good soils, farmers generally still make a reasonable income from agriculture. In the geologically poor regions, for instance the sandy regions and the peat soils of the Veenkolonien, farmers are more likely to perceive difficulties in making a living from agriculture and may thus be more inclined to participate in alternatives to diversify their income.

What is more, forestry practices are traditionally found mostly in the geologically poor (sand/peat) regions of the Netherlands, which are generally less suitable for intensive agriculture. A majority of the estates in the Netherlands is actually located in these areas. As estate owners and other foresters form another major group of potential agroforesters, this further underpins the expectation that agroforestry in these regions has a greater potential.

On the other hand, if it can be demonstrated that certain AF systems on good quality soils give better returns than the conventional mono-cropping system, land users in these areas may still be interested to shift to AF. Even though agroforestry may be more interesting for landowners in poor regions to increase and/or diversify income, it must be taken into account
that the prevailing biophysical environment always present a certain limitation to the choice of species. For instance, certain fast-growing trees (e.g. poplar) and other demanding tree- and intercrop-species may be unsuitable for regions with poor soils. Similarly, also maritime exposures can greatly reduce agroforestry options, as many plants and trees cannot withstand the strong and salty sea winds.

Summarizing, agroforestry systems may be not successful in all Dutch regions and the agroforestry design should be adapted to the local soil and climatic characteristics to attain maximum benefits.

**Mechanization**

The possibilities of mechanization will play a major role in the viability of AF, especially for farmers wishing to grow standard annual crops in the alleys. Therefore agroforestry designs should be adjusted to their machinery. Also possible future purchases of machinery should be taken into account, since trees are bound to their place. This means that the distance between the tree lines should leave enough space for the largest (in width) machines or even a multiplication of that width. In addition a buffer strip between the tree lines and the machinery of 0.5 to 1.0 meters should be considered. For root/tuber crops this distance may be bigger (e.g. 2.0 m) to allow for harvesting without damaging the trees (Mayus pers.com. 2004, Crop and Weed Ecology Group, Wageningen)

Farmers may prefer large distances (above 20-25 m) above small distances, both for the efficiency with machinery and to diminish shade-effects in order to maintain a healthy intercrop of light-demanding conventional crops. Also the headland in the design should be adjusted to the machinery in such a way that the farmers can easily make turns at the end without loosing valuable time. Related to this, farmers have suggested that large fields would be more suitable for AF. Small fields may be too inefficient in term of labour and land use.

On the other hand certain farmers may be open for agroforestry designs with a closer spacing and/or that need little mechanization and more hand labor, if the returns make up for the extra costs of labor.

8.3 Opportunities for the wider adoption of AF: Matching design and agroforester

The previous paragraph has outlined the major problems constraining the establishment of agroforestry, as well as ways to counteract these constraints. Despite the current constraints, the opportunities for agroforestry development are promising and the technical solutions are seemingly available.

Hence to promote agroforestry effectively, we need to develop and demonstrate agroforestry systems that match different types of land users. Naturally, the factors influencing the decision to establish an agroforestry field or not, can vary a lot between individuals. It can be assumed, that within a distinctive land user group (as estate owner, farmer, forester, hobby farmer) the variables shaping the perception of agroforestry are (to a certain extent) similar.

This section will shed a light on the prospective of agroforestry for some major groups of land users. Three major groups of potential agroforesters are distinguished, namely farmers, foresters and small-scale/hobby-farmers.

To give an idea of possible innovative designs, adapted to the local conditions and the individual wishes of the future agroforester, for each land user group one or more possible
scenarios will be given. It must be kept in mind that these are meant as example; no calculations were done on the optimum tree density, and the design may not be optimal. Also subsidies and markets were not taken into account.

8.3.1 Farmers

Farmers are the biggest group of ‘potential agroforesters’ in the Netherlands, considering the area they have in use. For farmers silvoarable and silvopastoral systems are the most logical choice. Firstly, a silvoarable and silvopastoral system can be designed such, that the farmer can apply his common machines. Secondly, they can be easily integrated into their farm management. In this way, the shift from agriculture to agroforestry is smooth. The farmer can continue with the usual crop rotation on the agroforestry field for several years, depending on the design. This means that at the establishment phase only the tree component requires new skills. At a later stage, when trees are tall, the farmer might grow shade tolerant forage and/or intercrops or stop cropping.

Innovative farmers may want to optimize the AF system using new crops and are ready to invest in new cultivation and marketing methods. Despite the larger efforts and higher risks, the cultivation of specialty crops may be more profitable, particularly when the trees are tall. Well chosen species may i) be better adapted to the agroforestry environment, ii) require labour out of the season, and iii) produce valuable products for niche markets.

Also farmers who maintain their standard crop could consider to grow a shade tolerant or specialty crop on the tree strip, e.g. Christmas trees, fruit shrubs, flower bulbs, decorative florals, mushrooms and flowers for honey production. Otherwise the tree strip could be kept bare (and free from weeds) by spraying, mowing or mulching or left as fallow. The first is an expensive solution the latter may lead to contamination of the intercrop by weeds, pests and diseases.

Finally crops for the production of non foods, as fiber and biomass, seem to have good prospects and show high potential for agroforestry applications, in particular for intensive farms.

With regard to the woody component, most farmers would prefer trees with early returns, either from wood or secondary products (Chapter 7). Hence fast growing species or species that yield products as fruits, nuts and other products seem reasonable options. Also tree thinning may generate early income.

Cooperation amongst farmers and cooperation between farmers and foresters may help to combine interests, knowledge and skills and could support the realization of agroforestry. Likewise cooperation between farmers and institutions like state-forestry or nature organizations may be very useful.

Below, several agroforestry scenarios are sketched for farmers. Simple designs of silvopastoral and silvoarable systems, including just one tree species (e.g. walnut, poplar or cherry) and one crop species (e.g. grass, a cereal, maize or vegetables) may be most easily to adopt for large farms. Most research until now has focused on such designs and clear examples can be found in various sources (e.g. SAFE 2004, Oosterbaan et al 2004, Garrett and McGraw 2000, Clason and Sharrow 2000, Dupraz and Newman 1997, Williams et al 1997). Although simple designs are easy to manage and easy to investigate, possibly more benefits can be gained when a system comprises more than one tree and or crop species and/or when the choice of the intercrop over time is adapted to the changing agro-ecological circumstances within the system. Therefore the below proposes slightly more complex designs. These designs are more challenging and may be more labour intensive. It must be understood that these are just proposals for innovative designs and that their value has not been proven. Moreover they may be not so attractive to highly mechanized intensive
farmers, but rather to innovative farmers, interested not only to optimize the farm economy, but also the farm ecology and diversity. Considering the current lack of subsidies on agroforestry systems however, they may well be more profitable than common simple designs.

**Agroforestry scenario 1**

**Silvoarable system comprising poplar, fodder crops and small fruits**

**Farmers profile**
- the farmer prefers a fast returns from the tree compartment, but would also like to harvest a high quality log to add to his pension or to build up capital for the next generation.
- the farmer prefers to maintain a fodder crop as long as possible to feed his livestock and to get rid of the livestock’s dung
- if revenue losses of (part of) the grain intercrop appear to become too high, the farmer is open to alternatives that are more economical

**Environmental and technical conditions**
- the soil is moderately rich and moist, but well drained
- the farmer has/uses a sprayer of 15 m width
- a minimum distance of 1 m is kept between the tree and the intercrop

**The agroforestry design and management practices**

**Establishment and early agroforestry phase:**
- chosen is for a good yielding poplar cultivar, which preferably comes late into leaf
- the orientation of the tree rows is north-south to minimize shade effects on the intercrop and to form a buffer from the western wind
- the distance between tree rows is 32 m, allowing for 2 runs with the 15 m sprayer and a 1 m buffer strip on either side of the trees (width of the tree strip is 2 m)
- the tree to tree distance within a row is 5 m to make up for the large between row distance
- between every two trees within the tree rows one shrub of gooseberries or black currents are planted
- the initial intercrop may be a rotation of any fodder crop, e.g. fodder beets, silage maize, grass and cereals; the intercrop width is 30 m. For fodder beets a larger distance between tree and crop (2 m) may be needed for harvesting, making the intercrop width 28 m for fodder beets.

**Second agroforestry phase:**
- after 5 – 8 years the crop yields adjacent to the tree line becomes low through shade. Therefore the intercrop width is restricted to 15 m, allowing for one run with the sprayer
- the distance between the trees and the intercrop is now 8.5 meters on either side and the entire tree line strip has a width of 17 m. It is chosen to grow shade-tolerant varieties of gooseberries and black berries on the tree strip which is more or less shaded during the day.
- 2 rows of gooseberries and black berries are planted at 3.5 and 6.5 m from the poplars, with a distance of 2 m within the row. This leaves enough room for the development and picking of the berries
- from now on the intercrop strip is only planted with either fodder beets, grass or cereals. Maize may cast too much shade on the berries
- during the whole cycle the poplars are regularly pruned to prevent knots and to reduce shade effects and problems with the machinery

**Harvest and yield expectations**
- at year 20-25 the poplars are ready to harvest
- the first planted berries will start producing after 2 years (year 8) and achieve full production at year 10
- all crops will produce until year 20-25, when the poplar logs are harvested

**Alternative options for management**
- planting poplar at 3 m within the row and thin later
- plant fast growing ornamental trees as pussy willow or curly willow within the poplar rows and/or along the poplar rows. The branches can be harvested after several years and sold to the floral industry for early profits, will suppress weeds and may reduce pruning costs
- plant flowers such as daffodils within the tree rows. These will give little competition, are adapted to partial shade and will provide additional income
- replace light demanding fodder crops with leafy vegetables as soon as shade becomes too strong
- instead of decreasing the intercrop strip at once from 30 to 15 m, this could also be done gradually, if the machinery can be adapted to intermediate widths

**Remarks**
- possibly at a certain age the poplars will start casting to much shade for the narrow intercrop strip or even for the berries/currants. A solution may be either to plant in a wider pattern, to thin and/or prune the poplars to decrease shading, to change to more shade tolerant intercrops or a combination of several of these options.

**Agroforestry scenario 2**

**Silvoarable system comprising walnut, food crops and hazel**

**Farmers profile**
- the farmer prefers a fast returns from the tree compartment, but would also like to harvest a high quality log to add to his pension or to build up capital for the next generation
- if revenue losses of (part of) the intercrop appear to become too high, the farmer is open to alternatives that are more economical

**Environmental and technical conditions**
- the soil is a moderately rich and well drained open soil
- the farmer has a sprayer of 18 m width
- a minimum distance of 1 m is kept between the tree and the intercrop

**The agroforestry design and management practices**

**Establishment and early agroforestry phase:**
- an early bearing walnut cultivar is planted at 20 m x 7 m, allowing for one machinery run with the 18 m sprayer and a one meter buffer strip on either side of the trees
- within the row between every 2 walnuts 2 shrubs of hazelnuts are planted, at 2.5 m from the walnuts
- the orientation of the tree rows is north-south to minimize shade effects on the intercrop and to form a buffer from the western wind
- the initial intercrop may be a rotation of any crop, e.g. vegetables, silage maize or cereals with a width of 18 m and tuber crops as potatoes, sugar beets, fodder beets with a width of 16 m (larger distance between tree and crop needed for harvesting)
- after several years only leafy vegetables are planted as intercrops, to minimize underground competition with the walnuts, which could delay nut production

Second agroforestry phase:
- at year 7 three double rows of hazelnuts are planted to substitute the annual intercrop. The centers of the double rows will be located at 5, 10 and 15 m from the walnuts. The hazels will be spaced 2 x 2 m within the double rows
- the whole agroforestry plot will be under sown with a grass-clover mixture, which is most useful for mechanical picking and can be harvested as hay or silage
- during the whole cycle the walnuts are regularly pruned to establish a straight stem and to reduce shade effects and problems with the machinery
- it may be necessary also to prune or even coppice the hazels regularly to maintain enough space for machinery.

Harvest and yield expectations
- after 7 to 8 years the walnuts start producing commercially. The nuts can be mechanically harvested on the pasture that will be well established in the autumn of year 7
- crop yields till year 7, then yields from vegetables
- the hazels will be commercially bearing in year 4/5. The double rows will then be 3 m wide, leaving 2 m between the rows for harvesting equipment
- the hazels and walnuts will be productive until year 50, when both are harvested

Alternative options for management
- hazels may also be substituted by Buckthorn (*Hippophae* spp.) or Azerole (*Crataegus azerolus*)
- walnuts may also be planted at 3 m within the row and be thinned later
- plant Christmas trees in the tree line and along trees. These can serve as nurse trees, forcing the walnuts to form straight logs and reducing pruning costs. They can be harvested after 5-10 years and replaced by shade-tolerant species

Remarks
- it may be worthwhile to apply organic cultivation methods as soon as the hazels are planted, since hazels produce well without fertilizers and pesticides and thus the products will gain an additional value

Agroforestry scenario 3
Silvoarable system comprising wild cherry and small fruits

Farmers profile
- the farmer is a fruit grower and is interested to try an alternative for the standard short- and medium-stemmed orchards

Environmental and technical conditions
- the soil is a rich and moist sandy clay soil and well drained

The agroforestry design and management practices

Establishment and early agroforestry phase:
- a cherry cultivar with good fruit production and good log production is planted at 7 m x 7 m
- between each 2 cherries in the row, 2 bushes of black currants and gooseberries are planted
- *Cornus canadensis* is planted within the row to form a productive groundcover, meanwhile decreasing the need to weed
- at a 5 m wide strip between the cherry-rows a crop of strawberries is planted
- netting is stretched above the trees to protect the fruits from being eaten by birds

Second agroforestry phase:
- after 4-5 years the strawberries are replaced by a double row of black currants and gooseberries
- during the whole cycle the cherries are regularly pruned to establish a straight stem and to reduce shade effects and problems with the machinery
- grass is mown regularly to obtain silage feed and to reduce competition and pests

**Harvest and yield expectations**
- the cherries will come into commercial production in the fifth year
- the first planted berries/currants will get productive in year 3
- the *Cornus* will be productive from year 2 and may be sold as specialty products
- the later planted berries/currants will get productive in year 8/9
- after 40 years the cherry trees are ready to be harvested and sold as high quality wood

**Remarks**
- the berry-crops may get less productive at a certain moment due to their age. One option is to substitute them by young plants of the same species or by other (even more) shade-tolerant species. Another option is to substitute them by grass. At that moment the cherries may be strong and high enough to prevent livestock from damaging them
- the *Cornus* may need regular pruning to prevent them from encroaching onto the other intercrops

**Agroforestry scenario 4**

**Silvoarable system comprising alder standards, grass forage and willow coppice**

**Farmers profile**
- the soil is rather wet clay or peat soil, with a high ground water table
- fields are bordered by drainage ditches
- instead of buying more milk-quota, the farmer prefers to sell some and invest it in diversifying his farming system

**Environmental and technical conditions**
- the soil is rather wet clay or peat soil, with a high ground water table
- fields are bordered by drainage ditches

**The agroforestry design and management practices**

Establishment and early agroforestry phase:
- rows of black and red alders are planted at 10 m x 2 m in the grass sward, in the direction of the ditches and bordering the ditches
- the grass in the alleys is regularly cut as silage

Second agroforestry phase:
- after 2-3 years, when the alders are well established, willow cuttings are planted in the alley
- the willows will be coppiced every 3-4 years to produce biomass

Harvest and yield expectations
- the alder standards can be harvested after 20-40 years and sold as valuable veneer
- after that they may be either left to resprout to produce new standards after thinning, or used as coppice for biomass as well
- after about 20 years, when the growth potential decreases, the willow coppice must be replaced by new cuttings

Remarks
- the willow coppice can be used to produce heat (e.g. for the homestead or a glasshouse) or electricity on farm, be processed at a cooperative or be sold to other parties
- the willow branches may also serve as woody ornamentals or can be processed into baskets and other valuable products

8.3.2 Foresters

Foresters may be private foresters (e.g. estate owners or farmers with a patch of forest) or forest managers working for institutions as state-forestry or nature organizations. For pure foresters the adoption of forest farming practices seemingly is the most simple and logical option. Estate owners who also practice agriculture may have other interests and needs, similar as those described in Section 8.3.1. The design also depends of the initial situation, i.e. bare land or established forest.

As for farmers, the design should be adjusted to the owner’s interest and willingness to take risks and to invest in new knowledge and markets. The majority of the specialty crops mentioned in Section 5.4 may well fit in a forest farming design. Many of these may produce very valuable products for niche-markets. Further value may be added by processing these products.

A possibly less demanding option may be the production of free-range meat, e.g. chickens, turkey, pigs and deer.

Agroforestry scenario 5

Forest farming system comprising hardwood species and wild simulated ginseng

Forester’s profile and site conditions
- a forest owner already has (semi-)natural forest, which he would like to generate more income, but preferably with little efforts
- the estate owner has the means to do long term investments and can take some risk of failure
- the soil is a natural humus-rich and well drained forest soil

The agroforestry design and management practices
- the existing forest is thinned in autumn to make room for ginseng cultivation and to achieve 70-80% shade. Slow growing hardwood species are maintained
- beds where the ginseng is to be grown are marked with downed tree trunks
- the leaf litter and competing understorey plants are removed
- topsoil (10-15 cm) is harrowed and stratified seeds are planted 1 cm deep in the beds in rows 45 cm apart and 10 cm within the rows
- seedbeds are covered with the removed leaf litter

**Harvest and yield expectations**
- seeds can be yearly harvested after year 4 and either sold or used for sowing new seedbeds
- ginseng roots can be harvested after 10-12 years, after which a new cycle can be started
- ginseng can be sold as wild simulated ginseng and hence earn a good price

**Remarks**
- it is unknown how ginseng will grow under Dutch circumstances
- if the root is of lower quality, profits of the system may be considerably lower

**Scenario 6**

**Forest farming system comprising hardwood trees, sugar maples (syrup), chestnuts (nuts) and gourmet mushrooms**

**Forester’s profile and site conditions**
- a forester already manages a (semi-)natural forest on a rich sand, which he would like to generate more income
- the forest owner is interested to produce valuable specialty products for niche-markets

**The agroforestry design and management practices**
- the existing forest is thinned and only slow growing hardwood-species are maintained
- hardwood stems form the thinning are inoculated with shii-take spores and placed between the trees
- on open spots sugar maples and chestnuts are planted

**Harvest and yield expectations**
- after 9 months the first mushrooms can be picked
- after 8-10 years the first chestnuts can be picked
- after about 15 years the sugar maples are big enough to be tapped
- shii-takes, chestnuts and maple-syrup can be sold to local shops, restaurants and on the biological market, directly or as processed products

**Alternative options for management**
- if the forest is fenced pigs, deer or turkeys may be introduced to produce valuable meat for the biological market

**Remarks**
- it is unknown sugar maple will produce much syrup under Dutch circumstances.
  Otherwise it still produces a valuable hardwood
8.3.3 Hobby/small-scale farmers

Last but not least, agroforestry may offer very interesting features for the increasing group of small-scale and hobby land users. As this group can take greater risks, they may be more open to innovative land use strategies and to adopt agroforestry. Moreover, this type of land user could afford to go new ways of farming which offer more than direct economic advantages. They may serve as an example for more conservative conventional farmers and foresters. However, also here counts that these people should first be made aware, informed and trained with respect to agroforestry.

Depending on the possibilities and wishes, this heterogeneous group may apply any of the innovative agroforestry practices mentioned in Section 2.4, most of which were given examples of in the previous Sections on farmers and foresters. Particularly interesting for hobby-farmers, are forest gardening systems, which can provide timber, fuel, a variety of food, flowers, medicines and other products for home consumption or marketing. Forest gardening designs can be fully made according to the wishes and creativity of the forest gardener. They may comprise a limited number of species in practical arrangements, but may also be a seemingly unorganized mix of numerous species, resembling the structure of a natural forest. Below one example of a possible forest gardening scenario is given.

Scenario 7:

Forest gardening system comprising a multifunctional mix of tree and crop species

Landowners’ profile and site conditions
- the owner has a patch of pasture and an old orchard with high-stem apples and pears
- he would like to turn this into a system, which is visually pleasing and produces a variety of food and other products for the family, and maybe some for selling
- he has enough money and time to invest in setting up the system

Environmental and technical conditions

The agroforestry design and management practices

Establishment and early agroforestry phase:
- along the western side a hedge of red and black alders, willows and Christmas trees is planted, to reduce wind speed and to produce timber, firewood, twigs for baskets and Christmas trees for selling
- the pasture is planted with rows of walnuts, chestnuts, plums, robinia, strawberry trees, Siberian pea trees, mulberries, juneberries and chokeberries and will form the top layer of the forest garden. At some places the density of the trees is low, leaving open areas for light demanding intercrops.
- the tree lines in the pasture and the orchard are interplanted with lower trees as hazels, willow (coppice), crabapples, *Eleagnus* spp., sea buckthorn, azeroles (*Crataegus azerolus*) and cornelian cherry. Also in the alleys some of these species may be planted, depending on their demands regarding light. They should be planted on spots that are expected to provide good growth conditions, now and in the future.
- under delicate fruits as the strawberry tree and the mulberries, the grass sward is maintained. Amongst the grass spring flowers such as daffodils can be planted to cut and sell.
- on other places the grass may be removed to grow vegetables, herbs, ornamentals and small-fruit
- on open spots in the forest garden, trellises will be established to grow grapes, brambles and kiwi-fruit

Second agroforestry phase:
- when the trees start casting more shade, light demanding vegetables can be replaced by shade-tolerant perennial vegetables, herbs and small fruits
- on places with dense shade, ferns or shade-loving flower bulbs and medicinals may be planted. Logs may be placed to produce gourmet mushrooms
- beehives are placed to pollinate the fruits and to yield honey and wax

Harvest and yield expectations
- the garden directly produces vegetables and fruits from the apple and pear trees
- after several years some of the fruit and nut trees will start producing for home consumption. Perennial vegetables and small-fruit can be used for home consumption or marketing. Mushrooms, flowers and other ornamentals, herbs and medicinals can be harvested for the market. Willows may be coppiced to provide twigs or firewood
- after 8 years most trees will produce plenty fruits and nuts for home consumption and to sell on the market

Remarks
- home processing of fruits, nuts and herbs can generate additional income
- fresh and processed products may be sold on farm or sold to local restaurants, shops or markets
- trees may need to be regularly pruned to maintain suitable growth conditions for other species
- depending on the availability of labour and money, the planting of trees can be spread over several years. This also gives more opportunity to adjust the choice and placement of new trees to the development of the system

8.4 Conclusions

The current agricultural surplus, the decreasing incomes of farmers and the increasing pressure on agricultural land to address more functions than arable production, demands us to take a wider view and to search for alternative and sustainable multiple land use systems in the Netherlands. Agroforestry may be an answer.

Agroforestry systems are very efficient in terms of resource use and could introduce an innovative (agricultural) production system that will be both environment-friendly and economically profitable. As such, agroforestry would fit perfectly to the current governmental policies aiming for an extensification of the agricultural system, leaving more room for nature and thus increasing biodiversity. Agroforestry has potential for various land user groups, as farmers, foresters and small-scale/hobby farmers and designs should be adjusted accordingly.

Growing trees in association with arable crops and/or livestock may improve the sustainability of farming systems, diversify farmers’ incomes, provide new products, and create attractive landscapes for both wildlife and people. Well designed silvoarable and silvopastoral system offer farmers the opportunity to apply common machinery and continue with the usual crop rotation on the agroforestry field for several years, providing sustainability of farm income in the early stage. There is a broad range of shade-tolerant crops, which
could produce valuable products at a later stage, both on a large scale for the bulk market and on a smaller scale for niche markets. Many of these are new for the Netherlands and require further research to assess their potential.

Forest farming systems have potential for private foresters and forest managers working for institutions as state-forestry or nature organizations. The production of shade-tolerant specialty crops or wild meat in existing forest stands may provide them with additional and diversified income. Forest gardening mainly has potential for small-scale and hobby farmers, who aim to cultivate for home consumption or produce a variety of products for the niche market.

Notwithstanding the promising opportunities of agroforestry, there are some important constraints that prevent the realization of the potential benefits. A major constraint is institutional. Agroforestry is not recognized as an official land use status. This discourages AF, as (in most cases) agroforesters can neither receive the grants for forestry plantations, nor those for agricultural crops. National laws oblige farmers to harvest trees before age 40 to prevent agroforestry plots shifting to a forest status and considerably decrease in value. Local regulations may impede the planting or felling of trees or force farmers to replant trees after felling.

Until now, there has been little attention (and funding) for agroforestry in Europe and The Netherlands. The lack of an adequate research base, practical demonstrations and extension agents and advisers who are able to address agroforestry issues hampers the development of agroforestry, as farmers and other land users often lack the knowledge and skills.

Although the concept is new, farmers in the Netherlands have indicated to be interested in agroforestry as an alternative land use system, if it proves to be economic in The Netherlands. At present only large farms may be able to face the investment costs for tree establishment, unless subsidies are provided for the smaller ones. Apart from the fact that most land users in the Netherlands are not aware of the possibility of agroforestry as an alternative land use system, few will be inclined to adopt it as long as the financial benefits are not proven and demonstrated. Applied research, practical demonstrations and institutional support are recommended to develop agroforestry on a large scale and to realize the benefits it offers.
References


Cannell, M.G.R., Noordwijk, M. van and Ong, C.K., 1996. The central agroforestry hypothesis: the trees must acquire resources that the crop would not otherwise acquire. Agroforestry Systems 33: 1-5.


CRB (Commissie voor de samenstelling van de Rassenlijst voor Bosbouwgewassen), 2002. 7e Rassenlijst van bomen. Lijst van aanbevolen soorten, rassen en herkomsten van bomen voor gebruik in bos, landschap en stedelijk gebied. Stichting DLO, Nederland.


Appendix: Major approaches to classification of agroforestry systems and practices

<table>
<thead>
<tr>
<th>Nature of components</th>
<th>Arrangement of components</th>
<th>Function (role and/or output of components)</th>
<th>Grouping of systems (according to their spread and management)</th>
<th>Socio-economic and management level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrisilviculture (crops and trees incl. shrubs/trees and trees)</td>
<td>In space (spatial) Mixed dense (e.g., homegardens)</td>
<td>Productive function Food Fodder</td>
<td>Systems in/for Lowland humid tropics Highland humid tropics (above 1,200 m a.s.l., Malaria) Lowland subhumid tropics (e.g. savanna zone of Africa, Cerrado of South America) Highland subhumid tropics (tropical highlands) (e.g. in Kenya, Ethiopia)</td>
<td>Based on level of technology input Low input (marginal) Medium input High input Based on cost/benefit relations Commercial Intermediate Subsistence</td>
</tr>
<tr>
<td>Silvopastoral (pasture/animals and trees)</td>
<td>Mixed space (e.g. most systems of trees in pastures)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrosilvopastoral (crops, pasture/animals, and trees)</td>
<td>Strip (width of strip to be more than one tree)</td>
<td>Protective function Windbreak Shelterbelt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Others (multipurpose tree lots, agriculture with trees, aquaculture with trees, etc.)</td>
<td>Boundary (trees on edges of plots/fields)</td>
<td>Soil conservation Moisture conservation Soil improvement Shade (for crop, animal and man)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Source: Nair 1993)
Attached report: Survey of farmers’ reaction to new to new silvoarable and silvopastoral systems in The Netherlands
Preface and acknowledgements

During my study Tropical Land Use, through various courses and an internship in Nicaragua, I got interested in agroforestry. I learned and personally observed the benefits of mixing trees and crops in tropical agro-ecosystems. It made me wonder, if agroforestry could also be valuable in Europe…it made me wonder also, observing the farming landscape in The Netherlands, why I only saw monotonous monocultures. I decided to find out though my thesis research, at the back of my head a dream to once establish an agroforest on my own farm.

With this report I want to shed a light on what the value of agroforestry could be in the Netherlands. I also hope to clarify what currently constrains the establishment of agroforestry. Hopefully this will make more people aware of the possibility of agroforestry as a sustainable multiple land use system and give handles for its successful application in The Netherlands.

This report would not have been what it is without the support of many people. First of all, I would like to thank Herman van Keulen, who put me on the right track, when I was looking for people in this field of research. He pointed me at Martina Mayus and at Anne Oosterbaan. I want to express my gratitude to both Martina and Anne for their important contribution to this thesis research. Without their experience and constructive comments for improvement and change, this thesis would not have been possible.

I would like to convey my appreciation to all the farmers and estate owners, who I visited during the survey, which formed an important part of this research. Thank you for your hospitality and your willingness to cooperate and share your views and ideas. You were a great deal of my motivation!

The survey was carried out as part of the EU funded research project SAFE (Silvoarable Agroforestry For Europe). The financial support, which has given me the opportunity to carry out this survey and present the results at a SAFE workshop in Toulouse, is gratefully acknowledged.

Last but not least, I would like to say thanks to my family and friends, who have greatly helped and encouraged me during this thesis.

“A farm can be regarded as a food factory and the criterion for its success is saleable products. Or, it can be regarded as a place to live, and the criterion for its success is harmonious balance between plants, animals and people; between the domestic and the wild; and between utility and beauty.”

Aldo Leopold
SUMMARY

The decreasing incomes of farmers, the overproduction of agricultural commodities and the increasing pressure on agricultural land to address more functions than arable production demands us to take a wider view and to search for alternative crops and sustainable multiple land use system in the Netherlands. Agroforestry, the production of trees and crops and/or livestock on the same plot, may be an answer. Research indicates that agroforestry systems are very efficient in terms of resource use and could introduce an innovative (agricultural) production system that will be both environmentally friendly and economically profitable. Agroforestry offers opportunities to achieve national policy goals of increasing tree planting and extensification of agriculture, improving farm biodiversity.

This study explores the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands. To get insight in the potential of modern agroforestry in the Netherlands, where currently agroforestry plays almost no role, a holistic approach was aimed for, assessing the ecological, technical and socio-economic aspects of agroforestry.

Through literature research the main agroforestry practices that would be appropriate and innovative were identified, the advantages and disadvantages of agroforestry related to the situation in The Netherlands were reviewed and a selection was made of tree and intercrop species that have proven their value in temperate agroforestry and/or are expected to be promising under Dutch conditions.

Based on website-information of the ministry of LNV (Agriculture, Nature Conservation and Fisheries) an overview was made of the restrictions of the Dutch forest law and of governmental subsidies, which may be eligible for agroforestry.

Land users’ perspectives on agroforestry will determine the eventual adoption of agroforestry. Their point of view have to be considered for the design of viable agroforestry systems. Therefore and as part of the Silvoarable Agroforestry For Europe (SAFE) project, a survey was carried out to investigate the attitude of Dutch land users towards agroforestry and to assess the conditions of acceptability of new agroforestry systems. In January 2004, the interviews were held with 27 farmers and 2 estate owners in two rather different regions in the Netherlands, namely the Achterhoek and North-Friesland.

Finally all information was synthesized and the constraints and opportunities for the establishment of new agroforestry systems in The Netherlands were discussed. Some examples of possible agroforestry designs are given for farmers, foresters and hobby/small-scale farmers.

Four distinct agroforestry practices are considered to be appropriate and innovative for The Netherlands, namely:
- silvoarable agroforestry, comprising widely-spaced trees and/or shrubs associated with arable crops
- silvopastoral agroforestry, a combination of trees, forage (pasture) and livestock production
- forest gardening, comprising multi-species and multi-storied dense plant associations, planted and/or managed in such way that they mimic the structure and the ecological processes of natural forests
- forest farming, the cultivation of edible, medicinal or decorative specialty crops as under-storey in (semi)natural woodlands
There is a variety of tree species that would fit in such practices in The Netherlands and provide wood and/or secondary products. Potential tree species are considered:

- multipurpose trees that have proven their value and their suitability to the Dutch environment, e.g. walnut (*Juglans* spp.), chestnut (*Castanea sativa*), hazelnut (*Corylus* spp.), sweet cherry (*Prunus avium*), and other fruit trees
- trees with fast (juvenile) growth, which may be suitable for short- and mid-term rotations (< 50 years), e.g. poplar (*Populus* spp.), willow (*Salix* spp.), alder (*Alnus* spp.), ash (*Fraxinus excelsior*) and maple (*Acer* spp.)
- multipurpose species that are not yet cultivated on a commercial scale in the Netherlands, but that have a potential for Dutch agroforestry mainly due to their secondary products, e.g. honeylocust (*Gleditsia triacanthos*), hawthorns (*Crataegus* spp.), *elaeagnus* spp., buckthorn (*Hippophae* spp.), strawberry tree (*Arbutus unedo*), mulberry (*Morus* spp.) and other ‘specialty trees’.

Most species of the last group are new for The Netherlands and/or have not yet been tested in agroforestry environments. Further research is required to assess their potential.

Growing trees in association with arable crops and/or livestock may improve the sustainability of farming systems, diversify farmers’ incomes, provide new products, and create attractive landscapes for both wildlife and people. Major disadvantages are the high investment costs, the necessity of new skills and possibly higher labour demands. Well designed silvoarable and silvopastoral system offer farmers the opportunity to apply common machinery and continue with the usual crop rotation on the agroforestry field for several years, providing sustainability of farm income in the early stage.

In The Netherlands, on the long term, the cultivation of common light-demanding crops in agroforestry systems may not be beneficial, because sub-optimal light conditions may seriously reduce crop yields or may cause problems with grain ripening. At this point, replacement of the light demanding crop by shade-tolerant forages and pastures may be considered. Livestock may benefit from the shelter provided by trees, but (young) trees need to be well protected to prevent damage.

There is a broad range of interesting alternatives, which can produce valuable products in the (partially) shaded alleys, both on a large scale for the bulk market and on a smaller scale for certain niche markets. Many of these are new for the Netherlands and require further research to assess their potential for agroforestry applications. Examples are:

- small-fruit species as *Vaccinium* spp., *Ribes* spp., *Rubus* spp., *Actidinia* spp. and various other berry species
- specialty crops as ornamental species, medicinals, specialty vegetables and gourmet mushrooms
- non-food crops for fiber and biomass production, as hemp and willow short rotation coppice

Small fruit species and specialty crops are particularly suitable for cultivation in forest farming and forest gardening systems. Crops for fibre and biomass production seem to have good prospects and show high potential for agroforestry applications, in particular on intensive farms. Instead of leaving tree strips in silvoarable and silvopastoral systems bare or fallow, they could also be grown with a shade tolerant or specialty crop on the tree strip, e.g. Christmas trees, fruit shrubs, flower bulbs, decorative florals, mushrooms and flowers for honey production.

Notwithstanding the promising opportunities of agroforestry, there are some formidable constraints that prevent the realization of the potential benefits. A major constraint is institutional. Agroforestry is not recognized as an official land use class. This discourages AF, as (in most cases) agroforesters can neither receive the grants for forestry plantations, nor those for agricultural crops. National laws oblige farmers to harvest trees before age 40 to prevent agroforestry plots shifting to a forest status and considerably decrease in value.
Local regulations may impede the planting or felling of trees or force farmers to replant trees after felling.

Until now, there has been little attention (and funding) for agroforestry in Europe and The Netherlands. The lack of an adequate research base, practical demonstrations and extension agents and advisers who are able to address agroforestry issues hampers the development of agroforestry, as farmers and other land users often lack the knowledge and skills.

At present only large farms may be able to bear the investment costs for tree establishment, unless subsidies are provided for the smaller ones. Apart from the fact that most land users in the Netherlands are not aware of the possibility of agroforestry as an alternative land use system, few will be inclined to adopt it as long as the financial benefits are not proven and demonstrated. Applied research, practical demonstrations and institutional support are recommended to develop agroforestry on a large scale and to realize the benefits it offers.

Although the concept is new for them, farmers in the Netherlands have indicated to be interested in agroforestry as an alternative land use system, if it is shown to be economically viable in The Netherlands. In the Achterhoek farmers are more open to agroforestry than in Northern Friesland, possibly because decreasing farm profits in the sandy areas and the limits to further intensification force farmers in this region to take a broader view on agriculture. Furthermore, they already have experience with trees and are more open to cooperation with neighbours and landlords.

Farmers in both regions see a lot of negative aspects of agroforestry, mostly technical such as mechanization, labor, and lower revenues on the intercrop. Most farmers emphasize the need for subsidies to compensate for the losses on the revenues of the intercrop and the expected extra costs for labour and tree maintenance. Another constraining factor is the lack of knowledge on tree management, tree returns and the market for tree products. Since most farmers have the experience to gain little or no money by the sale of tree products, they have little confidence in the profitability of agroforestry.

Since farmers have little or no experience with growing trees and agroforestry in particular, they find it hard to decide how they would design an agroforestry system. Farmers pointed out to need much more background information and practical examples to make reasonable decisions.

62 % of the respondents in the Achterhoek said they would like to try an agroforestry project. Only 27 % of the Friesian farmers were enthusiastic to try an agroforestry project. Whether respondents would adopt agroforestry would not so much depend on respondents’ age, but rather on profitability, the subsidies and on the (availability of a) successor.

To develop agroforestry in The Netherlands, first the forementioned structural constraints should be alleviated. Policies should recognise agroforestry as a legal land use status and adapt grant regulations and laws accordingly. Research and extension should get more acquainted with agroforestry, prove its benefits in The Netherlands and share this knowledge with farmers. Eventually agroforestry systems should be designed, which take into account the technical, ecological and socio-economic constraints and opportunities and the objectives of different land users. In Chapter 8 some scenarios are given for three potential groups of agroforesters in The Netherlands, i.e. commercial farmers, foresters and small-scale/hobby farmers.
# Table of Contents

PREFACE AND ACKNOWLEDGEMENTS.............................................................................................................1

SUMMARY....................................................................................................................................................109

1. INTRODUCTION ...............................................................................................................................................115
   1.1 GENERAL BACKGROUND................................................................................................................115
   1.2 AGROFORESTRY AS SUSTAINABLE AND MULTIPLE LAND USE SYSTEM ........................................115
   1.3 UNDERSTANDING AND CHANGING LAND USE PRACTICES ......................................................117
   1.4 CONCEPTS AND DEFINITIONS........................................................................................................118
   1.5 RESEARCH AIM AND QUESTIONS..................................................................................................119
   1.6 METHODOLOGY AND OVERVIEW OF THIS THESIS....................................................................120

2. POTENTIAL AGROFORESTRY SYSTEMS: CHARACTERIZATION AND MAIN PRACTICES.........................................................................................................................122
   2.1 INTRODUCTION........................................................................................................................................122
   2.2 CLASSIFICATION OF AGROFORESTRY SYSTEMS AND PRACTICES .................................................122
   2.3 CHARACTERIZATION OF INNOVATIVE AGROFORESTRY SYSTEMS FOR THE NETHERLANDS 122
   2.4 POTENTIAL AGROFORESTRY PRACTICES FOR THE NETHERLANDS ..............................................123
      2.4.1 Silvoarable practices.............................................................................................................124
      2.4.2 Silvopastoral practices........................................................................................................125
      2.4.3 Forest gardening......................................................................................................................126
      2.4.4 Forest farming........................................................................................................................127

3. ADVANTAGES AND DISADVANTAGES OF AGROFORESTRY..............................................................128
   3.1 INTRODUCTION........................................................................................................................................128
   3.2 ADVANTAGES OF AGROFORESTRY..................................................................................................128
      3.2.1 Ecological and environmental advantages ........................................................................128
      3.2.2 Socio-economic advantages..............................................................................................131
   3.3 DISADVANTAGES OF AGROFORESTRY...........................................................................................133
      3.3.1 Negative ecological interactions ......................................................................................133
      3.3.2 Socio-economic disadvantages.........................................................................................135

4. TREES FOR TEMPERATE AGROFORESTRY SYSTEMS, IN PARTICULAR THE NETHERLANDS..................................................................................................................139
   4.1 INTRODUCTION........................................................................................................................................139
   4.2 FAST GROWING TREES......................................................................................................................139
      4.2.1 Short rotation trees .............................................................................................................139
      4.2.2 Mid-term rotation species..................................................................................................141
   4.3 MULTIPURPOSE TREES...................................................................................................................141
      4.3.1 Upper storey trees.................................................................................................................141
4.3.2 Lower storey trees ................................................................. 147
4.4 ‘SPECIALTY TREES’ WITH POTENTIAL FOR AF ........................................... 148
   4.4.1 Upper storey trees .............................................................. 148
   4.4.2 Lower storey trees .............................................................. 151
4.5 CONCLUSIONS ............................................................................. 152

5. INTERCROPS FOR TEMPERATE AGROFORESTRY SYSTEMS, IN PARTICULAR
   THE NETHERLANDS ........................................................................... 154
   5.1 INTRODUCTION ............................................................................. 154
   5.2 CONVENTIONAL AGRICULTURAL CROPS ........................................... 154
      5.2.1 Cereals, maize, potatoes, sugarbeets and fodderbeets .................. 154
      5.2.2 Vegetables ................................................................. 156
      5.2.3 Pasture and forage .......................................................... 156
         5.2.3.1 General ................................................................. 156
         5.2.3.2 Forage production for hay or silage .............................. 158
         5.2.3.3 Pasture ................................................................. 158
   5.3 SMALLFRUIT ............................................................................... 160
      5.3.1 General ............................................................................. 160
      5.3.2 Well known species ........................................................ 160
      5.3.2 Less known species with potential ....................................... 162
   5.4 SPECIALTY CROPS ..................................................................... 163
      5.4.1 Woody ornamentals ......................................................... 164
      5.4.2 Herbaceous ornamentals .................................................. 164
      5.4.3 Medicinal plants, herbs and aromatics ............................... 166
      5.4.4 Specialty vegetables ......................................................... 170
      5.4.5 Gourmet mushrooms ....................................................... 171
      5.4.6 Apiculture ................................................................. 172
   5.5 CROPS FOR FIBER AND BIO-ENERGY PRODUCTION ......................... 172
      5.5.1 Hemp ............................................................................. 172
      5.5.2 Short-rotation coppice for bio-energy ................................. 174
   5.6 CONCLUSIONS ............................................................................. 176

6. GOVERNMENTAL REGULATIONS AND SUBSIDIES WITH (POSSIBLE)
   RELEVANCE TO AGROFORESTRY .................................................. 177
   6.1 RESTRICTIVE REGULATIONS ....................................................... 177
   6.2 GRANTS ON TREE PLANTING AND/OR MAINTENANCE ................... 177

7. THE REACTION OF DUTCH FARMERS TO NEW SILVOARABLE AND
   SILVOPASTORAL SYSTEMS ........................................................ 181
   7.1 INTRODUCTION ............................................................................. 181
   7.2 OBJECTIVE AND METHODOLOGY .............................................. 181
   7.3 RESEARCH AREA ........................................................................ 181
   7.4 RESULTS ....................................................................................... 182
   7.5 CONCLUSIONS ............................................................................. 184
8. SYNTHESIS AND DISCUSSION: ROADMAP FOR ADOPTION AND DESIGN OF NEW AGROFORESTRY SYSTEMS

8.1 INTRODUCTION

8.2 LIMITING FACTORS AND SOLUTIONS FOR THE ADOPTION OF AF

8.2.1 Lack of basic knowledge and skills

8.2.2 Structural constraints

8.2.2.1 Research and extension

8.2.2.2 Governmental policies

8.2.3 Other socio-economic factors

8.2.3 Practical limitations

8.3 OPPORTUNITIES FOR THE WIDER ADOPTION OF AF: MATCHING DESIGN AND AGROFORESTER

8.3.1 Farmers

8.3.2 Foresters

8.3.3 Hobby/small-scale farmers

8.4 CONCLUSIONS

REFERENCES

APPENDIX: MAJOR APPROACHES TO CLASSIFICATION OF AGROFORESTRY SYSTEMS AND PRACTICES

ATTACHED REPORT: SURVEY OF FARMERS' REACTION TO NEW TO NEW SILVOARABLE AND SILVOPASTORAL SYSTEMS IN THE NETHERLANDS
1. INTRODUCTION

1.1 General background

In the Netherlands there is an ongoing debate about the role and future function of rural areas. Many farmers are worried about their future. Decreasing incomes and more regulations cause daily 8-10 farmers to stop their business (Aarde, boer, consument 2002). At the same time, there is an increasing pressure on agricultural land to address more functions than production, for instance bird-protection and other wildlife support, environmental protection, maintenance of cultural elements and recreation. To keep agriculture viable in the Netherlands, where land is scarce and societal demands are high, we need to look at land use systems, which can combine several of such functions.

In traditional agriculture, crops were selected to match the site, which generally experienced only the amendment that one farmer could achieve with his own hands (Ashton 2000). Risks were spread by the use of a variety of crops and the heterogeneity in genotypes was large. Fallows, crop rotations and mixing of crops, trees and/or animals were used to maintain and improve production. Furthermore hedges and trees were often included in the farmland to provide field boundaries and services as timber, fencing, firewood, edible products, fodder, shade, nutrients and wind-protection. This resulted in a diverse and small scale rural landscape.

Since the 50s, through the introduction of agrochemicals and enormous advances in crop genetics and agrotechnology, combined with policy measures favoring intensification, agriculture has changed enormously. Farming has been highly intensified and specialized and food production has risen considerably. The arable land has undergone amendment and homogenization of site conditions to fit the specific cropping demands of a farm, often comprising only one or a few species and genotypes. Although rotations of several species remain an important part of modern farming, intercropping is being practiced at a very limited scale.

Nowadays we realize the negative side effects of this type of farming, for instance groundwater pollution, eutrophication of water bodies, low biodiversity and overproduction and measures are being taken to promote a more extensive and diversified land use.

Moreover, developments after the second world war targeted at separation of functions like agriculture, nature conservation and recreation. At present, increasing demands for land in the Netherlands has resulted in an increasing pressure on agricultural land and the need for efficient use of this resource. Therefore the concept of multiple land use has received increasing attention in the last decades. Multiple land use is defined as “land use aiming at the generation of more than one type of product and/or services” (Londo 2002).

This altogether has led to a search for new and more sustainable land use systems, which can offer multiple products and/or functions. Within that context, this report explores the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands.

1.2 Agroforestry as sustainable and multiple land use system

The intensive production of agricultural and forestry monocultures is unique to advanced developed countries, while worldwide the separation of agriculture and forestry has proven to be difficult. Up to present, agroforestry has remained the primary land use approach in many parts of the developing world. Complex indigenous farming systems, producing a multitude of
products such as timber, firewood, food, fiber, forage and medicines have operated effectively for centuries (Nair 1993). In addition to a multitude of products for direct use and/or sale, such complex systems offer a level of environmental protection (i.e. conservation of the natural resources) unmatched by modern land use technologies (Young 1989, Nair 1993). The link of production and protection forms the basis for the concept of sustainability, which is central to international development activities aiming to break the negative feed-back relationship between intensive land use and progressive environmental degradation (Lassoie and Buck 2000).

Indigenous and modern agroforestry systems in the tropics have received ample attention during the last decades. Recently, the application of agroforestry in developed countries has been receiving more and more attention. Since the needs for enhanced environmental protection through sustainable land use will only continue to grow, it is expected that the interest in agroforestry will continue to grow, also in the Western world.

However less complex, recent findings indicate that also modern silvoarable production systems are very efficient in terms of resource use, and could introduce an innovative agricultural production system that will be both environment-friendly and economically profitable (SAFE 2004). Within this context, recently the Europe-wide SAFE6 project was set up, in order to further assess the validity of silvoarable systems and to suggest unified European policy guidelines for implementing agroforestry (SAFE 2004). Also current research on modern silvopastoral systems in the Netherlands within the framework of research on “multiple sustainable land use” within Wageningen UR, expressed the positive values and potentials of agroforestry (Oosterbaan et al. 2004). Furthermore the “Stichting Boslandbouw” has initiated several small-scale agroforestry plantings in the North of the Netherlands, which have proven to be profitable (Alterra 2003).

In many regions of the world, including most parts of the Netherlands, forests are ecologically the most optimum vegetation. Natural succession in these areas would eventually result in a forest stand. Contrary to common Dutch agricultural practices, the author of this report promotes the idea of working with natural processes rather than continuously attempting to control or fight against them. From this ecological perspective, it seems logical to implement well designed agroforestry systems as the agricultural production system in originally forested areas, since these come closest to the natural situation. Both ecological theory and empirical research suggest that mixed-species systems are indeed ecologically more stable (i.e. less susceptible to epidemic pests and diseases) and sustainable (i.e. more efficient in the use of above- and below ground resources) than monocropping systems (e.g. SAFE 2004, Ashton 2000).

Although modern agroforestry has proven its value in temperate America, and seems promising in temperate Europe as well, only few investigations have been undertaken on this subject in the Netherlands. It is only recently that modern agroforestry receives attention in The Netherlands and that researchers and other stakeholders with interest and knowledge of agroforestry are interchangeing their experiences and views (Alterra 2003).

No findings are reported on the socio-economic viability of agroforestry as a new farming system, i.e. little is known about the insights and attitudes of farmers and other land-owners, regarding agroforestry. In view of the increasing attention for sustainable farming and multiple land use, it is now the time to seriously regard the possibility of agroforestry as a future land use type in the Netherlands.

---

6 Silvoarable Agroforestry For Europe (http://www.montpellier.inra.fr/safe)
Traditional agroforestry systems in the Netherlands have largely disappeared, with the exception of some small traditional orchards and poplar pastures, while modern systems have not yet been developed. However, windbreaks and riparian buffers are widely applied there where the land is prone to erosion and the fields are bordered by open water, respectively.

To get insight in the potential of modern agroforestry in the Netherlands, where currently agroforestry plays almost no role, this report aims at a holistic approach. It will regard the potential of agroforestry from a rational technical, ecological and economic point of view, but will also consider land users’ perspectives on agroforestry, as these will determine the eventual adoption of agroforestry and are necessary in the design of viable agroforestry systems. To be able to understand and influence the potential of adoption of modern agroforestry systems, however, it is necessary to have a basic understanding of the variables that play a role in shaping human practices vis-à-vis their natural and social environment.

1.3 Understanding and changing land use practices

When considering land use practices (e.g. farming, forestry, agroforestry), one can distinguish between different domains of land use (Leeuwis and van den Ban 2004). Such domains are essentially different aspects that need to be considered while managing a land use system, namely technical, economic and social aspects. Important (sub)domains of land use practice that farmers and other land users are likely to take into account include (Leeuwis and Van den Ban 2004):

- in the technical domain: soil fertility, crop-protection, production and yield, storage facilities, spatial organization of the farm
- in the economic domain: income, profitability, marketability, taxes, investments, cash flow, credit, fixed costs, variable costs
- in the domain of socio-organizational relations, relations with: input providing organizations, organizations on the output-side, household and community members, farm laborers, religion

According to Leeuwis’ definition, the technical domain also includes ecological aspects of the land use system. Furthermore, land users have to coordinate their practices across different moments in time, i.e. they can do things with different time horizons in mind.

Similarly, Leeuwis argues that “the locus of agricultural decision-making is not so much the individual ‘head of the household’, but extends to household/community members and is also influenced by other actors in (or even) outside the agricultural production chain”.

This implies that the decision whether and how a land user will implement a certain innovation, in this case agroforestry, will thus not only be based on rational technical and economic considerations. Also other, often less tangible issues, such as identity, culture, conflict, religion, risk, trust can play a role in shaping land users’ practices. Leeuwis (Leeuwis and van den Ban 2004, adapted) summarises it as follows: “land use practices are shaped in a series of social interactions between different people at various points in time and in different locations, within the context of a wider social system”.

In all, people’s practices, i.e. what they do or not do (and how they respond to proposed alternatives), depend on what they aspire (i.e. what they want), believe to be true about the biophysical and social world (i.e. what they know), and (think they) are able and allowed to do (Leeuwis and van den Ban 2004).
This report will shed a light on the various technical/ecological, economic and social factors related to agroforestry and thus playing a role in shaping land users’ perceptions of agroforestry, which eventually will affect the potential of agroforestry in The Netherlands.

1.4 Concepts and definitions

Agroforestry
Agroforestry is characterised by a high diversity and variable scope of practices, therefore many definitions of this system exist. Lundgren (1982) gave a broadly applicable definition, which is also the definition used by the “The World Agroforestry Centre” (the former ICRAF) (2004):

*Agroforestry is a collective name for land use systems in which woody perennials (trees, shrubs, etc) are grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation or both; there are usually both ecological and economic interactions between the trees and other components of the system.*

In the context of this report, the definition of herbaceous plants is taken slightly broader than only crops and pastures; also other “intercrops” that give benefits on a short term, e.g. mushrooms, shrubs, Christmas trees and coppiced trees, are taken into account as possibility to grow in association with woody perennials, which give at least part of their benefits (i.e. wood) on a longer term than the intercrops.

It is the interactions that make agroforestry systems so very complex and different from monocropping systems. Interaction takes place aboveground (e.g. shading, evapotranspiration) and belowground (e.g. root interactions with respect to water and nutrients). The more the growth habits of the intercropped species differ from those of the woody elements, the less the competition for growth resources. Agroforestry is successful when resource capture and use is more efficient (complementary) than in monoculture, leading to increased overall production (Cannell et al. 1996). But AFS may also provide environmental improvements in the long-term, e.g. resulting from erosion control or organic matter improvements, that become noticeable only after several years. The same holds for the economic aspect, that comprises diversification in type and timing of income and a possible income increase due to higher yields.

The ecological and economic output of agroforestry depends on the complexity of the system, i.e. the characteristics of the system as well as the location of the site. Consequently, there is not one single perfect agroforestry system and, moreover, agroforestry is not the panacea land use system. This in combination with the fact that their success may only be noticeable after many years makes it very difficult to predict agroforestry benefits. However, extensive evidence for their potential benefits exist (Chapter 3).

Multi-purpose tree
A multi-purpose tree is defined as a woody perennial, that is purposefully grown to provide more than one significant contribution, to the land use system in which it is grown. Multipurpose trees may be grown for products of direct economic value (e.g. wood, food-products, flowers, medicines) and/or to generate services that do not, or not directly have economic value, such as protection, nitrogen fixation, biomass-production, purification of contaminated soil or ecological functions.
Sustainability
Sustainability or sustainable land use has been variously defined, but the essential feature is that sustainable land use combines production with conservation of the natural resources on which production depends (Young 1997).

The formal definition of the Food and Agricultural Organization (FAO), which is commonly accepted, is as followed:

*Sustainable agriculture and rural development are defined as the management and conservation of the natural base, and the orientation of technological and institutional change, in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Such sustainable development conserves land, water, plant and animal genetic resources, is environmentally non-degrading, technically appropriate, economically feasible and socially acceptable.*

1.5 Research aim and questions

The overall aim of this report is to explore the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands. This aim comprises four objectives:

- E. To explore the general value of agroforestry and to identify appropriate tree- and intercrop species for agroforestry in the Netherlands by means of literature and internet research
- F. To shed a light on governmental support and restrictions related to agroforestry
- G. To assess the interest of Dutch farmers and estate owners for agroforestry and to investigate the conditions of acceptability of new agroforestry systems by means of a survey among Dutch farmers
- H. Considering the results of A-C; to define constraints and opportunities for the establishment of agroforestry in the Netherlands and to propose innovative agroforestry scenarios for distinct types of land users

Below, each of the objectives is specified through several research questions. All questions refer to the Dutch situation.

Questions for objective A

4. What are the general characteristics of agroforestry systems that can play a role in the Netherlands and what are adequate and innovative agroforestry practices?

5. What are the possible advantages and disadvantages of agroforestry?

6. Which tree- and intercrop species are appropriate for Dutch agroforestry systems?

Questions for objective B

3. What are the legal constraints for the establishment of agroforestry?

4. Which subsidies (may) apply to the establishment and/or maintenance of agroforestry systems in the Netherlands?
Questions for objective C

3. What is the attitude of Dutch farmers and estate owners towards agroforestry?
   - under which conditions does agroforestry interest farmers or estate owners; i.e. what are the factors that can encourage the introduction of agroforestry systems at the farm scale (opportunities)
   - what are the factors that can discourage the adoption and introduction of agroforestry systems at the farm scale (constraints)

4. How can constraints for the introduction of agroforestry be removed or alleviated to make it acceptable for the Dutch situation?
   - which technical adaptations are needed for the introduction of agroforestry
   - which fiscal aspects need to be solved to allow the development of agroforestry systems
   - which kind and level of subsidy or other measures are needed for farmers to adopt agroforestry schemes

Questions for objective D

4. What are the major constraints for the establishment of agroforestry and how can we remove or alleviate those constraints?

5. What are the opportunities or how can we create favourable conditions for the establishment of agroforestry?

6. Regarding the constraints and opportunities, what are possible agroforestry scenarios for different types of land users in the Netherlands?

1.6 Methodology and overview of this thesis

The Chapters 2 to 5 address objective A, for which an extensive review of books, papers and web sites was undertaken.
   - Chapter 2 describes the main agroforestry practices, which are appropriate and innovative for the Netherlands.
   - Chapter 3 discusses the advantages and disadvantages of agroforestry systems, related to the situation in the Netherlands. This discussion is largely based on experiences with temperate agroforestry in developed countries.
   - Chapters 4 and 5 give a selection of tree and intercrop species that have a good prospective for application in temperate agroforestry. The list of species is restricted to those that have proven their value in temperate agroforestry and/or species that are expected to be promising under Dutch conditions.

Chapter 6 deals with objective B and provides an overview of the restrictions of the Dutch forest law and of government subsidies, which may be applicable to agroforestry. The greater part of this Chapter consists of web-based information of the ministry of LNV (Landbouw, Natuurgebeheer en Visserij)(LNV-loket 2004).

Chapter 7 addresses objective C. It consists of a summary of a farm survey, which was performed in the Netherlands within the framework of the EU-project SAFE. The purpose of the survey was to investigate the attitude of Dutch farmers and estate owners towards
agroforestry and to assess the conditions of acceptability of new agroforestry systems. The complete survey-report is attached to this report.

Chapter 8 deals with objective D and gives a synthesis of the results of the previous chapters. It discusses the implications of these results for the potential of modern agroforestry as a sustainable land use system in the Netherlands in general, and for different types of land users in particular. Several examples of possible agroforestry designs are given for each type of land user. Finally the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands will be discussed.
2. Potential agroforestry systems: characterization and main practices

2.1 Introduction

Agroforestry is a broad concept and comprises a whole range of different land use systems and practices. *Agroforestry systems* are distinctive types of agroforestry, at any level of generalization. Many classification systems and names are used to describe broader classes, local examples of agroforestry systems and anything in between (e.g. Nair 1993, Young 1997, Gold et al. 2000). In practice, ‘agroforestry systems’ is widely used, both in the broader sense and in the narrower sense, and the intended meaning is generally clear. Following Nair (1993), I choose to call the broader classes *agroforestry practices*, denoting a distinctive arrangement of components in space and time.

For the description and evaluation of systems and practices, several classification schemes have been developed. Appendix I gives an overview of the classification approach of Nair (1993), which is widely accepted. For this study, the classification criteria and framework proposed by Nair (1993) are applied in a simplified way to identify appropriate and innovative agroforestry practices for the Netherlands. Additional criteria for the identification of appropriate innovative agroforestry practices, were that the practices should have (potential) agro-economic value (i.e. adapted to the agro-ecological and socio-economic environment), but should not yet be widely applied (i.e. on a commercial scale) in the Netherlands.

2.2 Classification of agroforestry systems and practices

Nair (1993), who thoroughly reviewed the history of agroforestry classification, summarizes four criteria for classifying agroforestry systems and practices:

5. Structure of the component: This refers to the nature of the components (e.g. tree or crop) and their arrangement in space and time.

6. Function of the system: This describes the role and output (i.e. the purpose) of the components; major functions are production and protection.

7. Agro-ecological and environmental adaptability: This is determined by the agro-ecological zones where the system exists or is adoptable

8. Socioeconomic and management level: This is based on technological input and cost and benefit relations.

According to Nair’s classification framework, the first step to classify agroforestry systems is to define their structural (nature and arrangement) and functional aspects. Subsequently the agro-ecological and socio-economic aspects are used as the basis for grouping the system practices (Appendix I)

2.3 Characterization of innovative agroforestry systems for the Netherlands

These criteria for classification of agroforestry systems and practices are considered for identifying the characteristics of agroforestry systems with prospects for the Netherlands:
Criterion 1: Nature of the components and their arrangement in space and time
Agroforestry systems always involve a perennial woody component. Depending on the nature of the other system elements (crop, pasture and/or animals) the three major categories are distinguished:
   i) Agrisilvicultural, the mixture of crops and trees;
   ii) Silvopastoral, i.e. trees on pastures with grazing animals and
   iii) Agrosilvipastoral, the combination of trees, crops and pasture/animals.
Given the Dutch conditions, there is scope for all three categories, but mainly for the first two.

With respect to the arrangement in space and time of the agroforestry components, the spatial aspect is of major importance for the Netherlands. The spatial design directly affects the management possibilities and in particular the possible level of mechanization. A wide and linear arrangement of trees will allow the utilization of the conventional (large) machinery on intensive and/or large-scale farms. Denser or irregular arrangements will mean limitations towards mechanisation, but will have other (functional) advantages and may have potential for application at a smaller scale.

Within spatial arrangements of course also certain temporal patterns may occur, such as crop rotations, interpolation (i.e. sowing the next crop in the standing crop) and/or replacements of species. Considering the intensity of land use in the Netherlands, rotational agroforestry (i.e. the temporal separation of components) is expected to have little potential though. Rotational agroforestry, whereby arable crops are rotated with woody fallows, may be a good way to restore fertility lost during crop cultivation (Young 1997). Dutch agricultural systems, however, are very intensive and often have a high input of fertilisers, which is unlikely to change in the near future. Hence in this study, rotational agroforestry is excluded as a potential agroforestry practice for the Netherlands.

Criterion 2: Function of the system
It is striking that agroforestry with a protection function still exists in the Netherlands (e.g. windbreaks), while systems with the major purpose of production (e.g. grazed orchards) have virtually disappeared. Therefore, this report will focus on the potential for agroforestry systems, that (also) have a productive function.

Criterion 3: Agro-ecological and environmental adaptability
The Netherlands is rather homogeneous in terms of climate and relief. In this report some attention is given to system- and species adaptability to soil characteristics (soil-type, soil-depth, fertility) and to windy conditions.

Criterion 4: Socioeconomic and management level
With regard to the socio-economic and management level of potential agroforestry systems, those with low, medium and high inputs of technology are taken into account. Related to this, systems for commercial purposes, subsistence purpose and intermediates are considered as having potential for the Netherlands. Accordingly, tree- and intercrop species for various socio-economic and management levels are treated in Chapters 4 and 5.

2.4 Potential agroforestry practices for the Netherlands

Following his classification approach, Nair (1993) distinguishes between about 20 different agroforestry practices, which are denoted by their distinct arrangement of components in space and time (Appendix 1). The Association for Temperate Agroforestry (AFTA 2004, Gold
et al. 2000) in the USA, recognises only 5 categories of agroforestry practices, i.e. riparian buffer strips, windbreaks, alley cropping, silvopasture and forest farming. Other authors (ART 2004) also consider forest gardening, fertility plantings and contour buffer strips as practices for temperate agroforestry in developed countries.

Fertility plantings and contour buffer strips are irrelevant for the Netherlands. In the predominantly flat landscape, contour buffer strips, which are woody strips planted to stabilize sloping soils, would be of no use. Fertility plantings or rotational agroforestry are not considered an economically viable option for the Netherlands (Section 2.3).

Windbreaks and riparian buffers are already widely applied in the Netherlands and need little exploration. These traditional landscape elements are maintained or even replanted for the purpose of protection, i.e. prevention of erosion and water pollution.

The agroforestry practices silvoarable, silvopastoral, forest gardening and forest farming may play a future role in Dutch land use and farming. These practices are innovative and suitable for the Netherlands, and will be explained below.

The classification of agroforestry systems is rather broad and complex. It may not be easy to group a certain agroforestry system within one of these major categories of practices. For instance, it may be difficult to draw a line between a complex (i.e. multi-species) silvoarable system and a forest farming system. Moreover, agroforestry systems are dynamic systems, i.e. subject to continuous changes. An agroforestry plot may start as a silvoarable system, but may change into a silvopastoral system in later years.

Nevertheless, the following description of the four considered agroforestry practices gives an impression of the range of possible agroforestry systems for the Netherlands.

### 2.4.1 Silvoarable practices

Silvoarable agroforestry or alley cropping comprises widely-spaced trees and/or shrubs associated with arable crops. Often the woody elements are planted in single or multiple rows at wide spacing, creating alleys within which agricultural or horticultural crops are produced.

In the tropics, where the term alley cropping is used, the system generally include hedges of woody leguminous species, which are regularly coppiced to provide animal feed and biomass in order to maintain/restore soil fertility. The woody component in temperate zones usually comprises species, that provide high-value timber, veneer and/or fruit and are only slightly pruned to reduce shade effects on the intercrop. Although American literature (e.g. AFTA 2004, ATTRA 2004, NAC 2004, Gold et al. 2000, Williams et al. 1997) still practices the term alley cropping for such practices, European sources (e.g. SAFE 2004, Dupraz and Newman 1997, ART 2004) tend to call them silvoarable practices, indicating the difference in function of the woody component in temperate zones. In this report the term
silvoarable agroforestry will be used. Usually annual crops are grown simultaneously with trees to provide annual income while the trees will be harvested only after several years (fruit) or decades (timber). However, perennials could also be intercropped. Winter crops (i.e. autumn-sown) are very efficient users of the light available over the dormant season of deciduous trees.

The tree component typically includes species for production of valuable hardwood and/or fruits, or desirable softwood species for wood fibre production. The trees may be grown as standards in single or double rows, as pollards or as coppice. A further alternative is a triple row, with high-value timber trees sandwiched between rows of nurse trees (usually coniferous) which help train straight trees and are themselves thinned at a later stage (ART 2004).

Small scale growing of vegetables in orchards were common practice in temperate zones, but recently modern mechanized silvoarable systems are gaining increasing interest as an alternative land use system in the United States, Canada and Europe (e.g. SAFE 2004, ART 2004, ATTRA 2004, NAC 2004, Garrett and McGraw 2000, Dupraz and Newman 1997).

2.4.2 Silvopastoral practices
A combination of trees, forage (pasture) and livestock production is called silvopastoral agroforestry. The system is designed to produce a high-value tree component, while continuing production of the forage component indefinitely or for a significant time. The forage component usually consists of a permanent pasture, mostly grazed rotationally to allow regrowth and prevent tree browsing. In early years, the grassland can also be cut for hay or silage (this is actually a silvoarable practice). White clover, which is a rather shade-tolerant legume, is often included in the mixture.

Trees are grown as standards or as pollards, in single or multiple rows. These may be trees for timber, fibre or fuel wood, fruit or other valuable products. Nitrogen-fixing trees can be useful to supply nitrogen for the forage crop. Trees may also be maintained to provide shade, shelter and fodder for the animals, but for regions characterized by a highly modern and intensive agriculture (high input), which generally holds for the Netherlands, highly valuable trees will be necessary to be economically viable.
The trees are usually protected by some kind of shelter (e.g. a plastic tube or net), especially when trees are young (Section 5.2.3.3).

Silvopastoral agroforestry is a common traditional system in the Netherlands, for instance fruit orchards with sheep. Although much of the old practices were lost during intensification, modern silvopastoral systems are proving their value in temperate countries as the USA, the United Kingdom and France. Recently a few examples of modern silvopastures can also be found in the Netherlands (Oosterbaan et al. 2004).

Modern silvoarable and silvopastoral agroforestry systems are often similar in terms of tree species, tree spacing and tree function. Within a tree life cycle the system might be changed from a silvoarable to silvopastoral system, when crop yields are no longer economically remunerative.

2.4.3 Forest gardening
Temperate forest gardens are comparable with the home gardens in the tropics, where they often form a major part of the food producing system on which the rural people rely since ancient times. In temperate regions, forest gardens are quite a recent innovation, that has been inspired by the efforts of the British forest gardening pioneer Hart (1996).

A forest garden is a multi-species and multi-storied dense plant association, based on the coexistence of trees, shrubs and perennial plants. The different species are planted and/or managed in such a way that they mimic the structure and the ecological processes of natural forests. It is assumed that the local natural forest structure is the most stable and sustainable type of ecosystem in the given environmental conditions.

A forest garden is organised in up to seven layers, i.e. canopy trees, small trees/large shrubs, shrubs, herbaceous perennials, ground covers, climbers/vines and root crops. Within these layers, the positioning of species depends on many variables, including their requirements for shelter, light, moisture, good/bad companions, mineral requirements, pollination and pest-protection. Forest gardening may start with native forest trees, especially ones that produce fruit, nuts, or sap for syrup.

In temperate regions, the light conditions are much more limiting than in the tropics. Therefore, the species for the upper- and understorey layers must be chosen carefully. Usually, much use is made of shade tolerant plants, whereas light demanding crops are planted on the more open spots. The crops that are grown may produce fruits, edible leaves, spices, medicinal plant products, poles, fibres for tying, basketry materials, honey, fuel wood, fodder, mulches, game, and juice. A well-established forest garden can be virtually self sustaining and, when plant mixtures are appropriately selected, may be essentially free of pest and diseases (Hill and Buck 2000).
Forest gardens are often applied at a small scale within the permaculture movement, since they address sustainability, can be very productive and provide a variety of products, all at a low maintenance cost. Moreover, a well-designed forest garden can provide a certain degree of self-sufficiency. The main drawback of this system is that the establishment requires a large number of plants (high investment costs) and substantial work (high labour costs).

2.4.4 Forest farming

Forest farming is the cultivation of edible, medicinal or decorative specialty crops as understorey in (semi)natural woodlands. This means that when a (semi)natural forest is used for wood production and additional production, it becomes an agroforestry system. Forest farming does not include the gathering of spontaneously-occurring plants from native forests, which is called wild crafting.

In forest farming, the high-value specialty crops are cultivated under the protection of a forest canopy that has been modified and managed to provide appropriate conditions. It is a way of utilizing forests for short-term income while high-quality trees are being grown for wood products. The amount of light in the stands is altered by thinning, pruning, or adding trees. Existing stands of trees can be intercropped with annual, perennial, or woody plants.

Typically, a forest farm can be established through thinning an existing forest to leave the best trees for continued wood production and to create conditions for the understorey crop to be grown. The understorey crop is then planted and managed intensively to provide short-term income. Areas used for forest farming are usually small and systems usually focus on a single crop plus timber, but can be designed to produce several products.

The cultivation of medicinal herbs (e.g. ginseng) or gourmet mushrooms under forest conditions are common practices of forest farming in the US and Canada. In Europe however, forest farming seems to be little known and practiced.
3. Advantages and disadvantages of agroforestry

3.1 Introduction

Below an attempt is made to outline the potential advantages and disadvantages of agroforestry, which may occur in the Netherlands as a consequence of ecological and socio-economic factors. This summary of advantages and disadvantages will be illustrated with examples from literature. Often constraints for agroforestry can be removed or alleviated by choosing appropriate plant species, system design and management practices. General methods to counteract disadvantages will be discussed. However, it must be realized that it is very difficult to generalize advantages and disadvantages of agroforestry, which is a complex and dynamic land use system, in biophysical and economic terms. Biophysical and/or economic performances of similar agroforestry practices may vary with soil- and climatic conditions, subsidy regulations, price fluctuations and the socio-economic situation. A certain tree feature (e.g. being the host of insects), might be beneficial to the crop (tree hosts predators of crop pest) or disadvantageous (tree hosts pests of crop). Moreover, the output of a certain system changes with time. The long time horizon of agroforestry and the lack of experimental data (in particular over an entire agroforestry life cycle) form further difficulties for prediction of agroforestry benefits.

Hence this chapter should be understood as a guide for identifying the advantages and disadvantages that may occur in agroforestry in the Netherlands. The examples given in this chapter are useful to consider when designing a new agroforestry system.

Modern temperate agroforestry is an emerging technology and some uncertainty is associated with its adoption. Consequently, operators considering implementation of an agroforestry field should consider all potential advantages and disadvantages and evaluate the risks associated with its practice given the local conditions.

3.2 Advantages of agroforestry

Research findings indicate that modern agroforestry systems can be environmentally friendly and economically profitable. The association of high quality timber or multipurpose trees with arable crops and/or grazed pastures may i) improve the sustainability of farming systems, ii) increase resource capture and system yield, iii) diversify farmers' incomes, iv) provide new products to the wood industry, and v) may enhance biodiversity and create novel landscapes of high value (SAFE 2004).

The first part of this paragraph deals with the potential ecological and environmental advantages of agroforestry in The Netherlands. The second part treats the possible socio-economic advantages, part of which are a direct result of the ecological advantages.

3.2.1 Ecological and environmental advantages

Biodiversity and landscape quality

In agroforestry, the incorporation of multiple species into production systems, intrinsically results in a high biodiversity compared to monocultures. In monocropping, ecosystems are extremely simplified by human manipulation to favour the production of a single plant species, creating unsuitable and/or unattractive habitats for most wildlife species. For
Intensive timber plantations often the same applies. Agroforestry systems, through multi-species and structural diversity, add complexity to agro-ecosystems, bringing them closer to nature. Such systems can be seen as interface between nature and agriculture, providing new niches and opportunities for wildlife that do not exist in monocultures. Various studies show that natural fence lines, windbreaks and intercropping systems act as important refugia and corridors for wildlife and show increased numbers of animals such as birds and insects and small mammals (Williams et al. 1997).

Through the inclusion of trees in agricultural fields, the landscape does not only become more attractive for nature, but also for people. Most people appear to appreciate a diverse landscape. The presence of agroforestry fields makes agricultural landscapes more diverse, increase their aesthetic and recreational value and hence raises their overall landscape value.

**Efficient use of growth resources**

One of the major arguments for agroforestry is the fact that a mixed system of trees and crops might make use of resources as light, water and nutrient more efficient than a monoculture. The reason is that mixed systems use the resources differently in space (e.g. deep tree roots and shallow crop roots) and/or time (e.g. walnut starts to intercept light after the winter crop is already far developed, so that shade is not a constraint).

Research suggest that the roots of trees in agroforestry systems can form a safety net, catching water, nutrients and even pesticides (Garrett and McGraw 2000, SAFE 2004, Dupraz pers.comm. 2004, INRA, Montpellier). This network of roots may capture vertical and lateral nutrient-flows and greatly reduce their loss from the system (when trees are in leave). This means an increased efficiency of resource use, which may result in increased production (Section 3.2.2).

As resources are used more efficiently, less resources as water and agrochemicals may be required, to the benefit of the overall environment. Furthermore more biomass (i.e. products) may be harvested from an agroforestry field, than from an equal surface of a monocrop, i.e. the LER\(^7\) will be higher than one (Section 3.2.2). This means that with agroforestry less land surface may be required to produce the same yield, leaving a larger area for other purposes.

**Microclimate**

It is often assumed that trees will negatively affect crop performance due to shade effects. The positive effects of trees on the microclimate, which may improve the crop performance, are however often forgotten.

Through shade and wind reduction the microclimate in agroforestry systems will differ from that in monocropping systems. The impact of windbreaks on microclimate has been studied extensively. The system design as well as tree and crop height are important factors for the actual change in microclimate. Whether the modified microclimate benefits the crop development and production is also dependent on local climate and the crop species and crop phenological stage.

In the Netherlands, predominant winds are coming from the west and therefore a north-south orientation of tree strips gives most wind-protection. In addition to the geometrical

---

\(^7\) The Land Equivalent Ratio (LER) is the ratio of the area needed under sole cropping to the area of intercropping at the same management level to give an equal amount of yield. LER is the sum of the fractions of the yields of the intercrops relative to their sole crop yields (FAO definition).
arrangement and tree height, the tree shape and density of the tree crowns in a line have an impact on the degree of wind speed reduction.

Pollard et al. (1979) conclude, based on a large number of experiments with different types of hedge-like shelters in different countries and climates, that windspeed can be reduced up to 60% on the leeside. This results in a reduction of soil evaporation by up to 30% and soil moisture increase of up to 20%. The average soil temperature can be 10-15% higher on distances up to 6-8 times the height of the woody element. Brandle et al. (2000) mention that windbreaks with a density of 40-60% density (i.e. the ratio of the solid portion to the total volume of the windbreak) provide the greatest reduction in windspeed across the greatest distance. Few data are available on windspeed reduction in modern silvoarable and silvopastoral systems (single or multiple tree rows), but similar results may be expected. A reduced air flow in the field induces lower evapo-transpiration and higher air and soil temperatures. In the Netherlands such changes should usually enhance crop performance. The change in microclimate could benefit the development of crop pests on the one hand and that of their enemies on the other.

Yields for grain crops, horticultural crops and orchards have been shown to increase with protection of wind in temperate regions (Williams et al. 1997, Brandle et al. 2000). The Agroforestry Research Trust (2004) indicates that wind-protection may result in up to 25% increases in production and also increases bee pollination. Boer and Oosterbaan (2004) mention that cereals, maize and sugarbeets give higher yields on wind-protected sites. Fruit trees, but also horticultural crops are known to profit from decreases frost-damage. Hay and silage grass will dry slower in shade and can lose some of their mineral value.

Oosterbaan et al. (2001) mentions that the quality of pasture may decrease as a result of a shift to more shade tolerant grass-species due to decreasing light levels in aged agroforestry systems. Sharrow (1997) however, makes notice that forage growing under the shady, low wind environment near trees tends to mature more slowly and therefore, be lower in fibre and more digestible than that growing out in the open. Studies in Ohio and Missouri (USA) both demonstrated increased yield and quality (digestibility) of various grass forages grown under black walnut (Williams 1997).

The warmer microclimate in agroforestry systems may thus result in higher yields and/or quality of the intercrop. Rough-and-ready rules on the effects of the microclimate are hard to give though (van Wingerden et al. 2004).

Pests and diseases
Interactions between wildlife and farming systems can be positive but also negative, since the overall effect depends on the set of system characteristics. Some promising strategies for pest control may be achieved when the woody element is the host of a predator of a crop pest. This type of benefits arising from trees in arable land have been often overlooked. However, care has to be taken when choosing the tree species, since it might also host the pest. Certain aphids are known to use woody vegetations to survive the winter (Boer and Oosterbaan 2004). Furthermore trees can also create the right circumstances for pests and diseases. Potatoes for instance, may produce much less under the influence of tree plantings, due to Phytophthora and other diseases. Shade may give fungi more chance, decreasing the quality of crops that have to dry or ripen (Boer and Oosterbaan 2004).

Recent studies reveal that significant benefits may be provided by biocontrol agents of insect pests in or near wooded field corridors (Williams et al. 1997, van Wingerden et al. 2004). Van Wingerden et al. (2004) preliminary conclude that the chances of Green-Blue Veining (i.e. land and water non-crop elements) providing good conditions for pest control by natural enemies exceeds its risks as a source for pest outbreak. As such they consider the pest controlling functions of these Green-Blue Veins as a life support function, as a service from
nature to agriculture. Research indicates that small scale landscapes and plots narrower than 100 m (between woody elements) form the best habitat for natural enemies (van Wingerden et al. 2004). This suggests that the presence of woody elements can be beneficial for the intercrop in terms of pest control. Furthermore rows of trees can form natural barriers between the intercropping strips, hindering the spread of diseases. On the other hand, certain tree species could be also the host of the crop pest. Whether trees favour pest control or pest infection depends also on their impact on the microclimate in relation to potential crop pests.

Erosion and water quality
In many parts of the world agroforestry is primarily applied as a mean of erosion control. Since the Netherlands are rather plane, water erosion is restricted to some small areas in the south. Wind erosion, on the other hand, is known to be quite severe in the northern Netherlands, such as the Flevopolders. Millimetres (or tons) of topsoil are blown away every year, which means a loss of nutrients and often already scarce organic matter. Through the reduction of windspeed through trees, wind-erosion will be decreased (ART 2004, Brandle et al 2000), which indirectly will have its beneficial impact on the farm economy.

In the Netherlands, another major problem is groundwater pollution and eutrophication of water bodies as a results of the leaching of nutrients and agrochemicals from agriculture. As mentioned before, tree-roots in agroforestry systems can form a safety net, catching nutrients and pesticides (Garrett and McGraw 2000, Dupraz pers.comm. 2004, INRA, Montpellier), resulting in decreased groundwater and surface water pollution. Reductions of 70 % and more in contaminants such as nitrates are reported from the use of vegetative buffer strips along streams (Garrett and McGraw 2000). Although these strips are usually wider than those used in silvoarable and silvopastoral systems, the cumulative effect of several narrower strips may still result in filtering out a reasonable portion of the contaminants. It must be realized however, that tree roots will capture few nutrients as soon as they have shed their leaves, which is actually the season when leaching is usually greatest.

3.2.2 Socio-economic advantages

Diversification of income sources
Dutch agriculture is under pressure. Recent epidemics of animal diseases combined with government policies make it hard for farmers to make a living. Dutch farmers generally apply to two contrasting solutions. They either choose for a further intensification, specialization and mechanization or they prefer to extensify and diversify their farm income.

For this last group, agroforestry could be a suitable option. Agroforestry gives farmers the opportunity to spread their income and risks over different products and with time. Furthermore well chosen agroforestry combinations may result in a better spread and more efficient use of labour and machinery. At last, many agroforestry systems and their products lend themselves for value adding activities. Depending on individual preferences, farmers could for example choose to produce high-value specialty products for niche markets.

In general it is expected that demands and hence the prices for temperate hardwood will rise in the future. The reasoning behind this is that there is an increasing demand for hardwood, while imports of tropical hardwood will be more and more restricted. Also the demand for biomass production for fuel, fibre and waste management are expected to rise. The stronger the pressure on the price development of arable productions, the more attractive agroforestry will become as an economic alternative to conventional farming.
Production
Apart from diversification of income, agroforestry systems may have direct economic advantages. It gives landowners the opportunity to maintain a crop, while establishing trees on their land. The economic advantages are often difficult to predict due to the long time horizon of agroforestry systems and a lack of mature examples in Europe, but there is evidence that well designed agroforestry systems can be economically beneficial, when the LER is above 1 (Williams et al. 1997, Dupraz and Newman 1997, Huang 1998). Dupraz and Newman (1997) for example mention that with intercropping radishes in a pear orchard LER values of 1.65 to 2.01 were found, relating to economic and biomass yield respectively. Huang (1998) found LER values between 1.2 and more than 2.0 during the first five years of intercropping Taxodium ascendens with rape, wheat and soybean. Williams et al. (1997) mention the Ontario fruit producers, who routinely grow vegetables between their trees during the early years of orchard development. The advantages of their practices are clear: early returns, improved access to markets (diversification), better utilization of labour and equipment. The early benefits to fruit production included earlier production, larger early crops and higher quality early produce.

Such benefits can be attributed to cultural benefits associated with intercrop production (e.g. spraying for weeds and pests, irrigation, fertilisation). The tree might also capture some of the fertilizer. Through ploughing and underground competition with the intercrop, trees are forced to root more deeply, which is an advantage in drier periods (SAFE 2004, Dupraz pers.comm. 2004, INRA, Montpellier). In this way management practices for the intercrop ameliorate the growth of trees, leading to increased wood production and/or earlier yields (Huang 1998). In AF, a more efficient use of growth resources and an improved microclimate may also enhance yields and/or quality of the intercrop (Section 3.2.1).

Indirect economic benefits
Agroforestry practices may reduce the costs for labour and chemical input by suppressing weeds and pests. For instance, the tree might be a host of predators of crop pests and the intercropping of tree alleys decreases the weed problem heavily compared to a pure forest stand. Trees in agroforestry systems may benefit from the crop fertilisation, weeding and irrigation increasing wood and/or fruit production (Section 3.2.1).

Animals often show to appreciate trees for their wind-protection and shade. Trees have a climate stabilizing effect and reduce wind-chill and heat-stress. As such trees not only contribute to the well-being of the livestock, but may also have an economic advantage. Heat-stress for example is known to severely decrease milk production and quality. During cold-spells, protection from trees can cut the direct cold effect by 50 percent or more and reduce wind velocity by as much as 70 percent, making livestock require less feed energy (Clason et al. 1997, Williams et al. 1997). In both cases the livestock’s performance is improved and mortality is reduced.

Last but not least, the presence of woody elements usually enhances the landscape value (Section 3.2.1). The park-like landscape of wide spaced and well managed trees on arable land would be more attractive for recreation than the current open, for the eye rather monotonous Dutch countryside. Hence agroforestry may impede financial benefits through rewards from recreation and tourist activities. Examples are farm camping or lodgings, subsidies on tourist trails, fees on self-picking of fruits.
3.3 Disadvantages of agroforestry

The main possible disadvantages of agroforestry can be divided into negative ecological interactions between components, as competition for above- and belowground resources, and socio-economic disadvantages.

3.3.1 Negative ecological interactions

As explained in Section 3.2.1 the efficient use of growth resources is the basis of agroforestry. However, competition for above- and below-ground resources is often seen as the major constraint of mixing trees and crops. Therefore this section will treat on these aspects and the opportunities to minimize competition and optimize the use of growth resources. Further ecological disadvantages that could occur are increased pests and crop damage by animals as attracted by the presence of trees.

The below is divided in competition for light and for water and nutrients respectively, but it must be kept in mind that all growth factors are interacting and it is difficult to predict the net effect of trees on crops and vice-versa on a single factor.

Competition for light

Competition for light is often seen as a major problem, in particular in the Northern European countries. The degree of light competition depends on the incoming radiation as well as the tree architecture and the light requirements of the crop. For a given location, the problem of light competition can be approached either from the tree side or from the crop side.

A light demanding crop should be chosen only as long as the trees shade is tolerable and/or the crop production is still economically interesting (Paragraph 5.2). As soon as trees cast too much shade, more shade-tolerant or even shade-demanding intercrop species could be grown (Paragraph 5.3 – 5.5).

The tree architecture comprises tree height, canopy size, form and density and leaf angle distribution. These characteristics differ between species. For agroforestry systems, the wide spaced planting of trees with open and slowly developing crowns at sufficient distance to the adjacent crop will facilitate the light interception of the crop.

In addition to an appropriate combination of tree and crop species the farmer can manage tree shade by canopy pruning and tree thinning. If this is not sufficient the farmer might increase the distance of the crop to the tree line (narrower intercrop strip) (Dupraz and Newman 1997) or replace the crop by a shade tolerant one or stop cropping. The pruning can be to a smaller or a larger extent, depending on the shade situation.

Experiments with various pruned poplar-hybrids, planted at 10 m x 6.4 m, showed an average light interception of about 40% after 11 years, leading to no yield reduction of intercropped faba beans as compared to the control (Pasturel 2004). Pruning of lower branches up to a height of at least one log length (>2 m) has also proven to be a profitable solution to log quality where processors are willing to pay a premium for large, knot free-logs. This type of pruning produces an open park-like forest which is visually pleasing to neighbours and visitors (Section 3.2.1).

Competition for water and nutrients
Belowground studies are difficult and laborious and little research is done on the underground interactions between trees and crops. Most information on belowground interactions are obtained from measurements of soil water content and plant growth (comparison of yields in monoculture and mixed stands).

According to Dupraz and Newman (1997) trees in agroforestry usually grow slower than in a forestry control plot where trees are sprayed with herbicides on a 1-m radius, but they grow faster than in an unweeded forestry plot. Mayus (pers.comm. 2004, and Weed Ecology Group, Wageningen) however, remarks that this may only be true for initial growth. After some years (7 for poplar) the trees in agroforestry might grow faster than in monocultures, as was found in poplar-wheat mixtures in the South of France. In AFS in dry areas, perennial fodder and cereal crops appear to heavily reduce tree growth compared with that of agroforestry trees on bare (weeded) soil, but the growth is not significantly less compared with forestry controls (Dupraz and Newman 1997). Gold and Hanover (1987) give various examples of trials in which tree growth was higher with tillage and intercropping compared to stands with tillage alone. Also Dupraz and Newman (1997) mention findings of quicker tree growth in the first three years in agroforestry plots than in unweeded forestry.

The optimum maintenance within the tree row once the trees have been established is still unclear. The common practice is continuous weed control by various combinations of plastic mulch, herbicides and tillage, or the establishment of a low competition ground cover (Dupraz and Newman 1997).

Much of the underground competition will depend on root architecture. For agroforestry it would be most profitable to combine trees and crops that have different root architecture, for example deep rooting trees and superficially rooting crops. But most trees, when conditions allow this, develop a superficial root system, as crops do. Sharrow (1997) however notes that lower densities of trees and planting patterns in which trees have one or more sides in the open, typically used in agroforests, promotes rapid growth of trees and such trees may have greater taper than trees growing in closed canopy forest. This may mean that trees grown in agroforestry will more easily reach deeper soil layers, resulting in less underground competition. Dupraz (pers.comm. 2004, INRA, Montpellier) suggests that by intensive tillage, tree roots in the top soil will be laterally pruned each year and forced to grow in deeper soil layers. Consequently, the trees have access to water in deeper layers than the crop, reducing underground competition. Even more effective than tillage is ripping the outer edge of the tree line. In a similar way, root competition may also be alleviated by digging trenches between the trees and the crops.

In a mature silvoarable system in France (poplars and wheat), provisional results show that winter crops induce an unusual deep rooting pattern for the trees that help them to face the summer drought (SAFE 2004). Deep tree roots can form a web under the crop, that efficiently capture water and nutrients that would otherwise be lost by leaching and lateral waterflows (i.e. tree roots acting as a safety net)(SAFE 2004, Dupraz pers.comm. 2004, INRA, Montpellier). In case of drought, such trees will suffer much less from drought than more superficial rooting forest trees.

Research on 11 year old poplars showed that the root system was vertically and laterally well developed, suggesting that it would be less affected by water shortage than an annual crop (Pasturel 2004). Pasturel (2004) suggests to use wintercrops that develops a root system just after tillage, allowing the crop to establish before the tree roots begin to grow in spring In this same experiment with poplar and faba beans the number of pods per plant and number of seeds per pod the intercrop near the tree was reduced, probably due to competition for water and nutrients between trees and crop (light penetration was quite evenly distributed). However, averaged over the whole alley, there was no difference in number of pods per plant and number of seeds per pod between the silvoarable experiment
and the control crop area. It can be concluded, that the higher crop yield in the middle of an agroforestry alley compensated for the losses near the trees. This could be due to more favourable growth conditions (i.e. decreased intra-specific competition) in the middle of an agroforestry alley than in a monoculture, e.g. lower soil water loss by evapo-transpiration.

Because of their growth potential and long growing season, cool season forages (grass, clover, alfalfa) can be highly competitive with tree crops and able to greatly reduce tree growth, especially of newly planted trees (Dupraz and Newman 1997, Sharrow 1997, Garrett and McGraw 2000). A commonly used approach when planting trees into established forages is to spray a strip or circle around trees to provide a competition-free zone around each tree. Otherwise, by using annual intercrops for the first 3-6 years and consequently ploughing the intercrop area before planting the crops during these years, trees will form deeper roots during that period and may be little harmed by competition if a forage is established after that period (Section 5.2.3.1). Once trees overtop the crop and establish deep roots beneath the crop rooting zone, competition is largely one-sided, with trees possibly reducing under storey production, but under storey having little effect upon the trees.

Fruit trees are known to have a critical period for diameter growth to obtain good production. Hence initiation stages in fruit trees are very sensitive to competitive stress (Section 5.2.3.1). Timber-producing silvoarable systems may be more resilient to competition stress and that is amongst the reasons (see also Section 3.3.2) why future changes in silvorable designs from growing fruit trees to growing timber trees are predicted (Dupraz and Newman 1997).

In the Netherlands, where water (high and well distributed rainfall) and nutrients (high level of fertilisation) are generally not limiting, below-ground competition between trees and crops are expected to be small or even negligible. But in agroforestry systems on pure sandy soils and/or with low input, competition may be crucial, in particular in dry periods. Under such farming conditions, it is suggested to increase the width of the tree strip (i.e. increase distance tree-intercrop). This will result in decreased above- and belowground competition and hence in more constant square meter yields of the intercrop (Dupraz and Newman 1997).

### 3.3.2 Socio-economic disadvantages

In particular in countries as the Netherlands, where modern agroforestry is virtually unknown and as such not yet acknowledged, many socio-economic constraints can be expected. The following summarizes the major socio-economic factors, which may be disadvantageous for the implementation of agroforestry systems in the Netherlands.

**Grants/subsidies**

Even though the production of agroforestry may be higher than that of monocropping systems (Section 3.2.2), the economic output of a land use systems can vary enormously with the availability of grants. The available grant schemes in Europe are designed for forestry or agriculture, whereas agroforestry is not recognized. Moreover, the status agroforestry field does not yet exists. In contrast in France, new regulations allows farmers who plant trees in an agroforestry system to get compensatory payments for the uncropped area below the trees. Additionally in 2001 the French government introduced an agri-environmental measure that provides an incentive for farmers who manage agroforestry systems. The payments compensate farmers for the additional costs due to the trees. It was officially approved by the STAR Committee of the EU on 21 November 2001 and is valid for both silvoarable and silvopastoral systems. It is an additional five-year payment to cover the

---

9 Mesure No 2201 et 2202 Creation (2201) et Gestion (2202) d’Habitats Agroforestiers, AEM National Francaise Agroforesterie Validée
costs of forming an agroforestry system of at least 50 trees/ha, and the payment is equivalent to €240/ha/yr for trees with crops, €240/ha/yr for trees with sheep and €362/ha/yr for trees with cattle.

These regulations have resulted in an increased establishment of agroforestry systems (Liaigre, pers.com 2004, Ministry of Agriculture, Paris). Also in the Netherlands farmers and estate owners, particularly those with extensive farming systems, were interested to experiment with modern silvopastoral systems when local subsidies and compensations were made available (Oosterbaan 2004).

In other European countries, including the Netherlands, unfavourable grant/subsidy regulations currently often make monocultures economically more attractive than agroforestry systems. Edelenbosch (1994), for example, found that without any grants intercropping of poplars with maize, sugarbeets or grass would result in considerably higher net profits compared with poplar-monocultures. At present, however, the planting of fast growing trees in monocultures is subsidized, while planting them in agroforestry is not. This makes poplar in agroforestry economically less profitable than in a pure poplar stand.

However, there may also be examples, where agroforestry is economically viable under the current situation. Oosterbaan (2000) calculated that walnut orchards with cattle grazing the grass-intercrop would give a higher net benefit over 40 years than a grass monocrop, even when a management subsidy is received on the grass monocrop. Since modern agroforestry plays not yet a role in the Netherlands the eligibility of grants/subsidies have not yet been investigated. Eventually there are some existing national and regional subsidies, that apply on specific agroforestry practices. The latter will be discussed in more detail in Chapter 6.

Mechanization and labor
Difficult application of machinery, is often seen as a major problem of agroforestry systems. In modern AF, trees are typically arranged in lines at a certain distance. The distance between tree lines should be large enough to allow efficient use of the usual machinery. Machinery should be given plenty room, otherwise chances are higher to damage or even pull out trees (Swellengrebel 1990, Oosterbaan 2004). It may even be necessary to choose for a wider spacing than initially necessary, keeping in mind the future purchase of bigger machinery. If the agroforestry design and the machinery are synchronized however, mechanization in agroforestry will have little limitations.

Usually a crop free zone of one to two meter is kept on either side of the tree line and the lower branches are pruned. This not only allows the machinery to pass through easily, but also reduces competition. Furthermore it is important to reserve enough space at the headland to allow machinery to easily turn in and out of the intercrop strip between the trees, otherwise turning takes too much time and trees may be damaged (Swellengrebel 1990). Dupraz and Newman (1997) suggest a 14 m distance between the tree rows in experimental designs, as this would accommodate most of the mechanization constraints and allows for a 1-2 m bare strip along the trees. For intensive commercial farms a larger spacing (20 to 30 m for the Dutch situation) may be required, regarding the usual width of machinery.

In silvopastoral systems, where forage is also harvested for hay or silage, trees and individual tree shelters (if present) will mean a little yield loss and a lower labor-efficiency, since one has to circle around the trees. Oosterbaan (2004) found that higher tree densities have higher harvesting costs, higher yield loss and more tree damage than lower densities. Also in silvoarable systems, trees may mean that measures as ploughing, weeding, spraying and harvesting take more time per square meter of intercrop. On a hectare basis, it may take less time though, since a strip along the tree rows is usually passed over. Unknown is how contractors, who are usually paid per hectare, will react on agroforestry systems and the
possible increase of labor/ha related to that. Establishment, thinning, pruning of trees and transport of the wood will also take time, but this can be done in the quiet season and is less bound to specific times or weather conditions than other agricultural activities as ploughing, sowing and harvesting (Swellengrebel 1990).

If the agroforestry system consists of fruit or nut trees, harvesting of these fruits/nuts may also mean extra labor, especially in case of unmechanized harvesting. Furthermore the picking of fruits/nuts may limit the intercrop practices. Nuts for example will fall on the ground in autumn and can not be picked when an intercrop is present. Mechanical picking has proven to work best on grass (Section 4.3.1). For this and other reasons (see also Section 3.3.1) Dupraz and Newman (1997) predict that future changes in silvoarable designs will probably see a shift from growing fruit trees to growing timber trees.

In complex systems as forest gardens and certain forest farming systems mechanization is virtually impossible and can thus be quite labor-intensive. Especially the establishment of such systems will demand considerable efforts. Current practices indicate that they therefore usually take place on a relatively small scale (Hill and Buck 2000, ART 2004).

Finally many agroforestry systems will require an entrepreneurial attitude of the farmer or landowner. Since markets for many agroforestry specialty products will be small or undeveloped, the agroforester may have to locate or develop potential markets, e.g. local stores, restaurants, cooperatives (Josiah 1998). Furthermore also gaining information on production and processing of new products, i.e. technical expertise, may take time.

**Investments**
The development of agroforestry systems generally require high investment costs, which do only pay back on the long term. Good planting stock, tree-protection (individual tree shelters or fencing) and the labour needed for establishment are initial investments. The purchase of machinery, for example for pruning or picking of nuts, may be a secondary investment. An indirect investment is also the decreased benefits of the crop due to the occupation of productive land by trees, of which the economic returns only come in a later stage. It may be difficult for farmers, who are used to quick returns on investments, to make such long term investments.

**Markets**
Marketing of products from agroforestry systems may be a problem for farmers. Wood, fruits, nuts and other agroforestry products will perhaps be new for farmers and so is the marketing of these products. The agricultural sector is used that the marketing of agricultural products is perfectly regulated through cooperation of different companies for buying, transport and processing of the products and the selling of the final product. Such clear and organized marketing chain does not exist for the marketing of relatively small amounts of wood and other non-conventional agroforestry products.

Furthermore markets for certain agroforestry products may be limited compared to conventional arable products. This makes good market research and/or development necessary before investing in large scale production of such products. Related to the disadvantage of long term investments, investments in tree planting also means dependency of future markets. If the market for walnut production seems to be good now and prices are high, all may change if 100 other farmers also decide to invest in walnut production. Cooperation within the marketing chain and guaranteed prices as described above could also prevent such problems.
On the other hand, many of the possible (new) agroforestry products give innovative farmers the opportunity to diversify, to create new niche markets and to set up their own (short) market-chains. Furthermore, as mentioned before in 3.2.2, the perspectives for temperate timber are good.
4. Trees for temperate agroforestry systems, in particular the Netherlands

4.1 Introduction

In the Netherlands, an optimum tree species for agroforestry should meet the following criteria:
1 economically profitable in the relatively short term
2 adapted to the local circumstances
3 compatible with the crop- and/or livestock component

These criteria were applied for the selection of tree species that could fit in Dutch agroforestry systems. The selected tree species are described in this chapter.

The first criterion is based on the assumption that farmers usually have a short time horizon and they are used to relatively fast returns on their investments. Moreover the timber harvest of very slow growing tree species (50 and more years) would be outside the economic lifetime of many land holders. It is expected that tree species, which give early returns will be preferred by Dutch farmers and hence are most easily adopted (Chapter 7). Therefore this chapter focuses only on two groups of trees with potential for Dutch agroforestry:
- fast growing tree species that give relatively fast revenues from poles and wood
- slow growing species that, apart from their wood, provide secondary products in the short term, so called multi-purpose trees

First paragraph 4.2 lists trees with fast (juvenile) growth, which may be suitable for short- and mid-term rotations in Dutch agroforestry systems. In paragraph 4.3 a description is given of multipurpose trees that have proven their value and their suitability to the Dutch environment. A distinction is made between upper-storey and lower-storey trees. Upper-storey trees are trees that need full light for good production. Lower-storey trees are usually small trees, which tolerate (partial) shade. This makes them suitable for planting under larger trees. Finally paragraph 4.4 introduces multipurpose species that are not yet cultivated on a commercial scale in the Netherlands, but that have a potential for Dutch agroforestry mainly due to their secondary products. These will be called specialty trees. Again the species are distinguished between lower- and upper-storey trees. When possible the tree description includes information about the tree properties and demands in terms of their suitability for agroforestry in the Netherlands (i.e. if they fulfill criteria 2 and 3).

4.2 Fast growing trees

4.2.1 Short rotation trees

Short rotation trees are characterized by a fast growth, resulting in a wood of generally low density and value. Depending on the species, environmental conditions and wood utilization the tree life cycle comprises 10 to 30 years for poplar, willow and alder (Oosterbaan 2000).
Populus spp. (Poplar)

Poplar is probably the most cultivated short rotation tree in temperate agroforestry systems, e.g. in Great Britain, France, Italy, China and N-America. Poplars have always been important because of their fast growth, ease of reproduction and desirable tree shape. Production capacity, tree shape and vulnerability for diseases may greatly differ between various cultivars. According to Kuipers (pers. comm. 2003, Stichting Bos en Hout, Wageningen), a crossing of Populus deltoides and Populus nigra is useful in the Netherlands, but good results are also reported with hybrids of P. trichocarpa (e.g. Pasturel 2004, Burgess et al. 2003).

Poplar grows on rich sands, sandy loam, light and heavy clays with a groundwater level lower than 50 cm in summer (Oosterbaan 2000). Site selection has proven to be very important for attaining optimum yields (Burgess et al. 2003). Poplars are reported to be able to develop very extensive and aggressive root systems that can invade and damage drainage systems (PFAF 2004). Although shade effects can be reduced considerably by pruning the lower branches (Pasturel 2004, Burgess et al. 2003, Dupraz and Newman 1997) it must taken into account that the shade effects of poplar may be high compared to many other trees of the same age. Nonetheless it is frequently applied in agroforestry systems in temperate zones and good results are reported (e.g. Pasturel 2004, SAFE 2004, Dupraz and Newman 1997). An example are the trials of mixed tree and crops at two Universities in Britain, at Leeds and Cranfield. The mixed cropping system showed higher productivity than monocultures, due to more efficient use of light, nutrient and water. The crop development of for instance wheat was much advanced by the time that the poplar leaf area was fully developed, while water and nitrogen competition appeared to be low too. The reason for the latter is most likely that the trees’ uptake of water and nitrogen occurs at deeper soil depths than that of the crop (Wainwright 2004).

Salix spp. (Willow)

Willow has similar properties as poplar and has the advantage that it can grow on soils with high groundwater tables, making it especially suitable for spots in the Dutch polders where other trees are difficult to grow. It grows on wet sands, sandy loam and light clays with a groundwater level lower than 30 cm in summer (Oosterbaan 2000). A disadvantage of willow is its vulnerability for the watermark disease, especially from age 15 onwards (Oosterbaan 2000). Coppicing or pollarding decreases the risk of watermark disease.

Willow is mostly grown for fibrewood and clumpwood. Poplar is also grown for saw logs and veneer (Oosterbaan 2000). In short rotation coppice (SRC) systems these trees are also grown for biomass production and as such they could also function as an intercrop in agroforestry systems (see 5.4). Traditionally willow also yields twigs for the floral industry, basketry making, dike and waterside stabilization, fencing and many other uses.

Alnus glutinosa and A. rubra (Black alder and red alder)

Traditionally black alder was widely cultivated in the Netherlands for its fast growth, possibility to strive in wet conditions and its potential to fix atmospheric nitrogen and hence act as a natural fertilizer. Trees were usually planted along ditches as multifunctional riparian buffers, providing also timber, firewood and nitrogen fertilizer. The ancient system of narrow plots bordered with ditches and alder coppice are now seen as a cultural heritage and maintained through rules and subsidies (see Chapter 6).

Although black alder is traditionally regularly coppiced, Oosterbaan (pers.comm. 2004, Alterra Wageningen) indicates that standards of alder (20-50 years) can provide valuable timber. Since standards of alder are not frequently offered on the commercial wood market, demands seem higher than the offer. This may offer good opportunities for agroforestry, especially where traditional aldercoppice already exist and the traditional coppice-
management only has to be adjusted to also maintain standards for log production (Boer en Oosterbaan 2004)(Paragraph 6.1).
The same counts for the American red alder, which in an important lumber tree in N-America. It may be even more valuable than black alder, since it makes a good imitation mahogany and is used for cheap furniture etc. (PFAF 2004).
Alders grow well in wet poor or rich sands, sandy loams and light clays with a groundwater level lower than 20 cm in summer.

Other trees in short rotations
Garrett and McGraw (2000) note that the number of potential species for use in agroforestry systems are increased due to recent technological advancements in the use of juvenile soft hardwoods in making construction materials. As for poplar, the rapid juvenile growth of maple (Acer spp.) and birch (Betula spp.), yields high volumes per hectare on the short term, useful for soft-hardwood chips for the oriented strand board (OSB) industry as well as the pulp and paper industry.

4.2.2 Mid-term rotation species
Mid-term rotation species are trees that need a mid-term investment of 30 to 50 years to produce valuable wood for timber or veneer. Common forestry species as ash (Fraxinus excelsior) and maple (Acer spp.)(Section 4.3.1) may be very good options for their high quality wood and relative fast growth. According to Dupraz and Newman (1997) excellent clones of ash and maple have been selected for inclusion in silvoarable systems, but propagation techniques are not yet operative. Also robinia (Robinia pseudoacacia) and wild cherry (Prunus avium)( Section 4.3.1) are good wood producers on a mid-term.

4.3 Multipurpose trees
In the context of this report, a multipurpose tree is defined as a tree that has an economic value and that in addition to timber, provides directly marketable products on the short term.

4.3.1 Upper storey trees

Juglans spp. (Walnut)
In temperate agroforestry the common walnut (Juglans regia), the American black walnut (J. nigra) and the various modern cultivars of J. nigra x regia are commonly applied. The database of Plants For A Future (PFAF 2004) however, also mentions other Juglans spp. which may have good qualities for agroforestry, such as J. ailanthifolia (Japanese walnut).

J. nigra originates from the eastern half of the USA and has been the most valuable timber in North America. Much of the intercropping research and establishment in the USA has focused on black walnut. Its high timber value, aesthetic qualities, capacity for nut production, rapid growth, adaptability to management and certain foliage and root system characteristics makes black walnut an ideal agroforestry species (Williams et al. 1997). Black walnut is one of the last to break dormancy in the spring and one of the first to defoliate in the fall. This means more direct sunlight for intercrops and reduced competition for moisture, which is frequently in short supply in late summer (Williams et al. 1997). Even with full foliage (i.e. in summer), black walnut produces a rather light shade admitting slightly less than 50% of full sunlight, which is sufficient for most temperate-zone forage legumes and cool-season grasses which require about one-third full sunlight. Furthermore black walnut has a relatively
deep rooting system, leaving a shallow zone near the soil surface for development of companion root systems of intercrops (Williams et al. 1997). The dormant plant is very cold hardy, but the young growth in spring, however, can be damaged by late frosts (PFAF 2004). PFAF (2004) indicates black walnut does not fruit very freely in Britain. The tree is mainly cultivated for its wood and to a lesser extent for its fruits.

\[ J. \textit{regia} \], the common or English walnut, originates from Europe and Asia and produces both high quality wood and edible fruits. Recently it is gaining more and more interest in Western Europe as wood producer for afforestation on arable lands and for agroforestry (SAFE 2004, Oosterbaan 2004, van den Burg 1998). \[ J. \textit{regia} \] grows more slowly than \[ J. \textit{nigra} \] and needs up to 15 years to come into bearing. The dormant plant is very cold tolerant, tolerating temperatures down to about -27°C without serious damage, but the young spring growth is rather tender and can be damaged by late frosts (PFAF 2004). In the last decades, hardy clones (often hybrids of \[ Juglans \textit{nigra x regia} \]) are developed that combine both quality wood and quality nuts. These modern cultivars start fruit production after 3 years and they produce also well in The Netherlands (Oosterbaan en Valk 2000). For production of quality wood a rotation of 50 years can be considered as a minimum (Oosterbaan 2000). The foliage and root characteristics of \[ J. \textit{regia} \] are comparable with those of \[ J. \textit{nigra} \].

\[ J. \textit{ailanthifolia} \], the Japanese walnut, is cultivated for its edible seed in Japan. It has the potential for producing very superior nuts, especially if hybridized with \[ J. \textit{cinerea} \] (the white walnut or butternut) from North America. Trees can come into bearing within 3-4 years from seed (SAFE 2004). This is the hardiest member of the genus and also resistant to the attacks of most insects. The young growth in spring, however, can be damaged by late frosts. Japanese walnut requires a deep well-drained loam, slightly alkaline soil (PFAF 2004) and a sunny position sheltered from strong winds. Other characteristics are comparable to those of \[ J. \textit{regia} \] and \[ J. \textit{nigra} \].

Many combinations of intercrops with walnut have been tested, in experiments. Examples are cereals, maize, sorghum, soybean, rapeseed, canola, sunflowers, tobacco, aromatics, small-fruits, fruit trees, vineyards, alfalfa and grass (Nair 1993, Dupraz and Newman 1997). Research indicates that grasses grow well in walnut shade and are ideal for replacing row and/or specialty crops when shade reduces their yields (Williams et al. 1997, Oosterbaan et al. 2001). It can be expected that grass production under walnut will be little reduced in the first 10 years of establishment and will still be possible when tree crowns are closed (Oosterbaan et al. 2001). Silvopastoral experiments in the sandy Achterhoek region in the Netherlands show that at least during the first three years walnut has a very slow growth in height and diameter compared to chestnut and cherry. After three years the average crown cover of the walnuts was only a third of that of cherry (Oosterbaan et al. 2004). This suggests that walnuts will be less competitive for light, at least during the establishment phase, compared to cherry and chestnut.

Some investigations indicate that intercrops may suffer from the allelopathic effects of walnuts through the toxic substance juglone, while others do not (Oosterbaan et al. 2001). Juglone is formed out of a chemical which is dissolved out of the leaves, roots and twigs when it rains and is washed down to the ground below. Concentrations of juglone in the soil varies over the season (high in spring and autumn, low in summer)(Oosterbaan et al. 2001). Walnuts are said to inhibit the growth of many plant species, amongst others of maize, soybean and potatoes (PFAF 2004, Oosterbaan et al. 2001). Oosterbaan et al. (2001) mention an intercropping experiment in which the 62 % yield-reduction of maize was mainly attributed to the allelopathic effect of the trees.

On the other hand, in the French province Dauphiné walnut intercropping is traditionally practiced with a variety of crops, often cereals and maize (Dupraz and Newman 1997). In a French agroforestry experiment with cereals and oilseed rape no yield reduction was found during the first 8 years of tree establishment. Also in other experiments juglone seemed to
have little or no harmful effects on cereals (Mayus pers.comm. 2004, Crop and Weed Ecology Group, Wageningen). Moreover walnuts may decrease the production and biodiversity of weeds (Oosterbaan et al. 2001) and inhibit the establishment of undesirable forage species, thus reducing competition and allowing other more desirable species to grow uninhibited (Garrett and McGraw 2000).

In sum, more research is required to get a better understanding of the sensitivity of intercrop species to juglone and to make recommendations on the choice of companion crops, as allelopathic effects may have significant bearings on the total productivity of an agroforestry system. Nevertheless, the fact that walnut is one of the major species used in modern temperate agroforestry systems and intercropped with many species, may indicate that the positive effects of walnuts on the total system output may outweigh the negative allelopathic effects on the intercrop.

According to Williams (1997) a row spacing of 12.5 m is ideal for walnut production. Studies in Missouri have shown that black walnut planted on a good site will shade 12.5 m alleys within a 10-year period. If light-demanding crops are to be grown on such a site, row spacing must be increased to accommodate their needs. In contrast, a closer spacing and later thinning are required for shade-demanding intercrops such as ginseng. Within the rows the spacing can be shorter to provide enough surplus trees from which the best nut producers can be selected. For nut and wood production the trees should be thinned to approximately the most valuable 75 trees/ha within the first 25-30 years (Williams et al. 1997).

In France research is being done on cultivation on 4 m distances within the row, whereby the tree form is a vertical axis with horizontal side-branches. When the trees are fully grown, they are pruned with an inclined mowing bar, alternating the side of pruning year by year (Wertheim 1995).

Walnuts grow best on well drained sites and the soil should be fertile, calcium rich and allowing deep root growth. Ideal are (sandy) loam grounds (PFAF 2004, CRB 2002, van den Burg 1998). Unsuitable are poor sand grounds, heavy soils, shallow soils developed on calcareous layers (very rare in the Netherlands), peaty soils and very wet grounds. Van den Burg (1998) suggests that high soil fertility is not demanded for wood production, but rather for nut production. The hybrids of *Juglans nigra x regia* are usually less demanding on their growth place then their parents. For more specific information on growth places referred is to van den Burg (1998).

Various Dutch nurseries have selected and bred high quality (nut and wood) varieties fitted for the Dutch environment. At the experimental station for fruit growth in Wilhelminadorp various Walnut varieties were tested from 1974 onwards and the cultivars Broadview, Soleze, nr 139, Parisienne and Buccaneer appeared to give highest production. At 200 trees/ha (7 x 7 m), Broadview yielded just above 4 tons of nuts and Soleze between 3 and 4 tons of nuts as average over a three year period, making these the only profitable races considering prices in 1995 of € 2.25 – 2.70/kg nuts (Wertheim 1995).

Oosterbaan en Valk (2000) expect that walnut will start nut production after 3 years and at age 20 the trees will reach their full production of 18 kg/tree. They assume a yield of 0.5 m³ of valuable wood per tree after 40 years and have estimated the average net annual profits of a 1 ha plot of 100 or 25 trees/ha with grass and cows will be € 446 and € 595 respectively, or € 563 and € 622 respectively if the planting of the trees is subsidized. This calculation assumes an interest rates of 2 % and includes the removal of the stumps at year 40. In comparison: grass and cows only annually yields € 216 or € 523 with management subsidies.

Various machines have been developed for the harvesting of walnuts. In large plantings the trees are shaken mechanically, the nuts blown or harrowed together (after removing branches and smoothing the surface) and finally picked or sucked up mechanically before
cleaning. Hand machines are available for smaller plantings. They appear to work best on a grass surface (Oosterbaan et al. 2004). The mechanical picking of nuts means a severe limitation on the intercrop possibilities. In regions of France, where walnut and maize are commonly intercropped, the intercrop is either abandoned or reduced to a narrow strip as soon as the fruit-production becomes important (after 5-7 years) (Mayus pers.comm. 2004, Crop and Weed Ecology Group, Wageningen).

According to Nair (1993), various economic analyses have demonstrated that growing walnut solely as a timber crop is not economically viable, but that the addition of nut production and intercropping generally provides a positive benefit/cost ratio. In Southern France, results of a 9 year old silvoarable experiment of walnut (200 stems/ha) and durum wheat, showed a significant better growth of walnut in agroforestry than in the forest control. However, it was not clear if the increased growth was due to facilitation processes or due to a difference in water table and soil management (SAFE 2004). Within the SAFE project, economic analysis for walnut agroforestry systems is currently in work, since walnut next to poplar were seen to have a good potential in the Netherlands (SAFE 2003).

Castanea sativa (Sweet chestnut)
The sweet chestnut originates from the Mediterranean region, but is grown in North-Western Europe since Roman Times (van den Burg 1998). It produces a good quality wood and valuable fruits.

The requirements of the chestnut are comparable to those of (summer)oak (CRB 2002), but it is more shade-tolerant. It requires a deep, light and aerated soil. Oosterbaan (2000) advises rich sand grounds, sandy clay or light clay with a groundwater level deeper than 80 cm in summer. It prefers acidic grounds with as little CaCO3 as possible. Demands regarding soil fertility are not high, but it grows bad on very unfertile soils, calcareous soils, badly drained soils and heavy clays. Once established, chestnut is usually very drought tolerant (PFAF 2004, Ciesla 2002, van den Burg 1998). The tree prefers warm summers and mild winters and is sensitive to early and late frost.

Ciesla (2002) suggest that the preference of chestnuts for lighter soil provides an opportunity to utilize land that is marginally productive. Nevertheless, chestnut trees on heavier (clay) soils have been noted to perform in outstanding fashion if the drainage patterns prevent standing water or soil saturation for extended periods. Furthermore chestnut is deep rooting and as such may be compatible with intercrops. More specific information on growth requirements are given by van den Berg (1998).

In a silvopastoral experiment on sandy soils in the Achterhoek, the Netherlands, chestnut growth during the years of establishment was high compared to walnut, but lower than that of cherry (Oosterbaan et al. 2004). Three years after planting stem-diameter and crown cover were much higher than that of walnut and almost as high as for cherry. In term of light-competition, chestnut will probably take an intermediate position in between walnut and cherry.

For production of quality wood a rotation of 40 years can be considered as a minimum (Oosterbaan 2000). Oosterbaan en Valk (2000) assume that chestnut will produce 2 kg of fruit at age 5, 10 kg at age 10 and 20 kg at age 20. They expect a wood-yield of 1.0 m³ per tree after 40 years and have estimated the average net annual profits of a 1 ha plot of chestnuts (100 trees/ha) with grass and cows will be € 514 over 40 years if the planting of the trees is subsidized. This is including the removal of the stumps at year 40 and a 2 % interest rate. In comparison: grass and cows only annually yields € 216 or € 523 with management subsidies.

Harvesting techniques of the nuts are comparable to those of walnut. The nut collection in silvoarable fields will be accompanied with the same complications as described above for
walnut. Hence, as soon as the trees become productive and mechanical picking is required, intercrop possibilities are limited.

**Prunus avium** (Wild cherry)
The wild cherry or sweet cherry occurs naturally in the whole of Europe except the north and north-east. It traditionally produces both a highly valued wood and good fruit. For purposes of wood-production however, also fast growing clones are developed that produce no or only very small fruits (CRB 2002, Dupraz and Newman 1997).

Wild cherry grows well on most soils if not too poor and not too wet. Oosterbaan (2000) recommends rich sand, sandy clay, light clay and heavy clay with a groundwater level deeper than 50 cm in summer. For an optimum tree development, deep and rich soils are preferred, that are moist, but not wet. It thrives in a loamy soil. For fruit production heavy clays and badly drained soils are unsuitable. A bit of calcium is appreciated (PFAF 2004, van den Berg 1998). Although cherry prefers sunny and warm places, it is little sensitive to late frost and susceptible to wind damage. Specific information about the required growth conditions are summarized by Van den Berg (1998).

Wild cherry showed the fastest growth in the agroforestry experiment in the Achterhoek (Oosterbaan et al. 2004). This suggest that cherry might be rather competitive for light and that the intercropping period for light-demanding crops may be shorter than with chestnut and walnut. On the other hand, cherry would cast a light shade (PFAF 2004).

PFAF (2004) mentions that most members of this genus are shallow-rooted and hence likely to compete with the crop for belowground resources. Wild cherry would be a bad companion for potatoes, making them more susceptible to potato blight and is also known to suppress the growth of wheat. Moreover, it grows badly with plum trees, its roots giving out an antagonistic secretion (PFAF 2004).

A tree life cycle of a minimum of 40 years is needed to obtain a quality timber (Oosterbaan 2000). At a density of 100 trees/ha, Oosterbaan en Valk (2000) expect that cherry will start producing cherries after 5 years, will produce fruit only once every five years and at age 10 will produce 5 tons of cherries/ha. They assume a wood-yield of 1.5 m³ per tree after 40 years and have estimated the average net annual profits of a 1 ha plot of cherries (100 trees/ha) with grass and cows will be € 480 over 40 years if the planting of the trees is subsidized. This is including the removal of the stumps at year 40 and an assumed interest rate of 2 %. In comparison: grass and cows only annually yields € 216 or € 523 with management subsidies. It has to be noted however that cherries also need protection from birds, which is not included in the calculation.

**Prunus domestica** (Plum)
Plum naturally occurs from Europe to Western Asia. Its requirements and most characteristics are similar to those of wild cherry (PFAF 2004). Little research is done on its applicability for agroforestry, but its slow growth may make it a better companion tree than cherry.

**Malus domestica** (Apple) and **Pyrus communis sativa** (Pear)
Nowadays, in the Netherlands, most commercial fruit-orchards consist of dwarf varieties planted in dense rows with narrow strips of bare ground or grass in between. In principle this area could also be effectively used for the cultivation of winter/spring vegetables. The traditional high-stem fruit trees are planted at wider spacing. For centuries it was very common to let sheep or other livestock graze under the trees in high-stem orchards. With the introduction of dwarf varieties though, most high-stem trees were replaced and also the silvopastoral combination got rare (Gijsbers 1994).
Apple and pear trees can grow on most soils if well drained and moist, but prefer fertile soils for optimum development. Pears are quite tolerant towards excessive moisture and drought, if well established (PFAF 2004). They have a deep rooting system (CRB 2002), which may make them a good tree for agroforestry purposes.

The disadvantage of dwarf fruit trees is that they do not produce high quality wood logs and as such the income should come mainly from the fruit. In contrast, high-stem fruit trees can also produce valuable stems of excellent quality wood. Current subsidies on high-stem trees (Chapter 6) may compensate for the lower production and high labour costs and make high stemmed agroforestry fruit gardens viable again.

*Robinia pseudoacacia* (Black locust)
Black locust originates in the Appalachian mountains in the USA and has been grown in Europe since the 17th century. It is widely grown in Eastern Europe (Hungary) for its high quality wood. Special cultivars are also grown for honey-production. In the Netherlands it is usually grown as a park and lawn tree and it is only recently that it receives attention for commercial production. Apart from its pole wood and high quality saw wood, it bears rich fragrant flowers which are very suitable for bee-production and may also be valuable as a decorative floral. Hence this can lead to early benefits. Additionally it fixes atmospheric nitrogen, which may become available to the intercrop through its roots and leaf mulch.

*Robinia* is quite tolerant regarding soil quality, but wet, cold soils are unsuitable. It is resistant to drought and grows reasonably on dry unfertile grounds, if they are deep enough (van den Burg 1998). Oosterbaan (2000) recommends poor sands, dry rich sands, sandy clay or light clay, with a groundwater level deeper than 80 cm in summer. *Robinia* has a reasonable pH tolerance. The availability of P may be important in relation to the atmospheric N-fixation. Opinions on its susceptibility to late and early frost are divided. The temperature in the vegetative period is very important though, which may mean that the temperature in the NE of the Netherlands may be limiting to growth (van den Burg 1998). *Robinia* has a rapid initial growth, which gets less at a later stage.

*Robinia* comes into leaf quite late which could make it compatible with intercrops. On the other hand the root system is often found to be rather superficial and extensive, making it compete with the intercrop. Some authors claim though, that the root system can go quite deep, depending on the permeability of the soil and the groundwater level. Root architecture may also depend on the variety of *Robinia* (van den Burg 1998), which makes it important to make a good choice of cultivars for inclusion in agroforestry systems. CRB (2002) makes notice that *Robinia* forms a superficial rooting system on rich soils and a deeper rooting system on poorer soils.

*Acer* spp. (Maples)
*Acer*-species are fast-growing trees, which produce valuable wood for timber, veneer and fibre. Maple-species are easy to cultivate. They prefer a good moist well-drained soil but thrive in any soil. Some can even grow well on heavy clay and nutritionally poor soils (PFAF 2004). For the Dutch sycamore, *Acer pseudoplatanus*, Oosterbaan (2000) recommends rich sands, sandy loam and light clay with a groundwater-level deeper than 50 cm in summer. Maples tolerate some shade and are very wind-resistant, tolerating maritime exposure though it is often wind and salt pruned in very exposed areas (PFAF 2004, CRB 2002). PFAF (2004) makes notice that maples are bad companion plants, inhibiting the growth of nearby plants. This may limit their application in agroforestry. In North-America however, maples are often cultivated in forest-farming systems combined with ginseng or other medicinal plants.
Also other sources recommend maples for inclusion in agroforestry systems (Garrett and McGraw 2000, Dupraz and Newman 1997). Especially interesting for agroforestry-application is the North-American sugar maple (*Acer saccharum*) and its subspecies the big-tooth maple (*Acer saccharum grandidentatum*). Their wood is considered by many to be the most valuable hardwood tree in N. America (PFAF 2004). The sap of these trees is traditionally tapped and processed into maple syrup, which is used as a sweetener on many foods. It is used extensively in North America. In the Netherlands the market is only small but may be developed. The maple-syrup available in the Netherlands is now imported, but may be produced here as well. PFAF (2004) however, mentions that the best sap production comes from cold-winter areas with continental climates. Other maples, including the Dutch sycamore, also produce sugar-rich sap, but usually not in economic quantities (PFAF 2004).

### 4.3.2 Lower storey trees

*Corylus* spp. (Hazelnuts)

The Dutch hazelnut (*Corylus avellana*) is a large shrub and only gets 2-5 m high. It grows on calcium and humus rich soils in moist forests. For optimum production, the soil should be well drained, drought resistant and with a pH between 4 and 7 (Kwanten 2004). The Turkish hazel or tree hazel (*C. colurna*) is a tree up to 15 m high and is planted in the Netherlands as a park- and lane tree (Janson 1989). The Turkish hazel is resistant to drought. If the soil permits it, they will form a deep rooting system. Drought tolerance and deep rooting pattern are good properties for agroforestry systems, but there is no experience with respect to commercial nut production of the Turkish hazel in the Netherlands. The same counts for *C. maxima*, the filbert, a deciduous shrub from Southern Europe growing to 6 by 5 m. Both *C. colurna* and *C. maxima* have often been hybridized with *C. avellana* in breeding programs in order to develop superior fruiting cultivars (PFAF 2004). Hazels can grow in semi-shade (light woodland) or no shade (PFAF 2004) and may thus be used as a secondary storey of agroforestry systems, growing under taller trees. Hazels succeed in most soils, but generally produces more nuts when grown on soils of moderate fertility (PFAF 2004).

Although the Dutch hazel is an endemic species, commercial cultivation is still very limited. Foreign cultivars have been evaluated in experiments and are grown on a small scale, but sub-optimal yields and quality, and susceptibility to disease have prevented a further increase in acreage. It is only recently that, through selection and breeding of Dutch wild hazelnuts, new cultivars were developed with excellent yield potentials and other good quality characteristics (size, shape, taste, pellicle removal) (Schepers and Kwanten, in progress).

Hazels are generally not susceptible to serious pests and diseases and grow on most soils, if not constantly wet. This makes them especially suitable for organic cultivation. Nowadays there is a whole range of Dutch and foreign hazel cultivars available. Due to genetic differences, the productivity of the various cultivars is very variable. Kwanten (2004) mentions that good cultivars have an early production and yield about 4 kg of dry nuts per shrub in year 4 up to 12 kg from year 10. Meer van Oeveren (1997) says hazelnuts reach full production after eight years and 2,5 kg per tree is an average annual harvest, but yields may reach 8 or 9 kg, depending on race and year. Alternate bearing (not every year is a good seed year) often occur and are often related to weather. To prevent this as much as possible, it is recommended to arrange for good pruning and sufficient moisture and to choose for less susceptible varieties. With a good crop plan the average harvest over the first 15 years is 3500-4500 kg of dry (still hulled) nuts per ha of nut-orchard (Kwanten 2004). In Groningen still many varieties and under-stems are tested.
and selected for the Dutch environment. It is essential to include certain races for good pollination. Pollinators should make up about 20% of the planting to get good yields.

Research at the experimental station for fruit culture in Wilhelminadorp in the South of the Netherlands have indicated the potential to grow Dutch hazelnuts on a big scale. Nowadays 90% of the hazelnuts are imported from Turkey, but Dutch varieties can compete in quality and could take away the yearly insecurity of the Turkish production. Research suggest that the cultivation of hazelnuts can financially compete with that of sugarbeets (Dorresteijn 1996).

Fully grown trees of the best producing French cultivars yield 4500 kg/ha dry nuts including the hull, or 2000-2500 kg of dry dehulled nuts. These are harvested by up to 4.5 m wide ‘sweeping machines’ and are artificially dried. With these methods French hazelnut production has risen considerably since the 80’s, both through improved cultivars and new plantings. In the Netherlands the harvest is usually coordinated by ‘De Notenunie’ and boarded out to a contractor.

Meer van Oeveren (1997) mentions also an example of an innovative Dutch farmer who rebuilt a liquid manure tank into a hazelnut picking machine.

Good experiences were noted on the organic intercropping of hazel, walnut and the woody shrub sea buckthorn (*Hippophaë rhamnoides*, see Section 4.4.2) since 1996/1997 on a sandy soil in the Noordoostpolder in the province of Flevoland (Schepers and Kwanten, draft in progress). Rows were alternatively planted with Sea Buckthorn and nuts (walnuts and hazelnuts) The distance between the rows was 3.5 m. In the rows the sea buckthorn plants were planted 1.2 m apart. In the other rows, hazelnuts and walnuts were planted alternatively with a distance of 3.5 m.

Berries of the sea buckthorn are harvested since 1999, but the plants have to be pruned dramatically to prevent competition with the hazels and walnuts. The sea buckthorn plants will have to be completely removed in the near future. The hazelnuts started to produce in 2002. In 2003 the average yield of three cultivars and the pollinators was a little over 1 kg dried nuts/plant. The large size of the nuts, the high internal quality and the organic certification make the nuts into a very attractive product.

### 4.4 ‘Specialty trees’ with potential for AF

The following section will give a selection of further trees, with potential for application in Dutch agroforestry. The selection comprises trees that show good performance and appear to be, or used to be of economic value in either the Netherlands or in other temperate countries. They comprise mainly fruit trees and some other trees producing marketable products on a short term. Most of these ‘specialty trees’ are not cultivated on a commercial scale in the Netherlands and consequently most of their products have not yet an established market in the Netherlands. This gives the innovative agroforester the opportunity to search and develop niche markets for their products. Market-research is recommended before applying such trees.

#### 4.4.1 Upper storey trees

*Gleditsia triacanthos* (Honeylocust)

Research suggest that the American native honeylocust (*Gleditsia triacanthos*) has great potential for agroforestry. Garrett and McGraw (2000) mention that *Gleditsia triacanthos* by nature has small, sparse foliage and a long period of leaf retention. The root system develops from a central taproot that can extend downward to 3-6 m permitting the tree to
absorb water and nutrients of great depths. Moreover, it usually has fewer lateral roots than many other potential agroforestry trees, which minimizes its competition with the companion crop. These characteristics makes honeylocust interesting for inclusion in agroforestry systems. It succeeds on most soils, so long as they are well drained and can grow on nutritionally poor soils (PFAF 2004).

PFAF (2004) makes notice that this species likes long hot summers and may thus not produce well in maritime climates. Further research may thus be necessary to confirm their value in the Dutch climate.

Research findings (Dupraz and Newman 1997) show the potential of Gleditsia triacanthos as a fodder tree for ruminants. The pods of selected varieties appeared attractive to sheep and to have good feeding value. Sheep fed only with Gleditsia pods gained 135 g/day, but combining pods and rough feed would probably have a higher retention time in the rumen and therefore allow even higher digestibility of the pods. A variety with soft seeds easily broken at ingestion or rumination would have a protein digestibility as high as 70 or 80 %, making Gleditsia pods a viable alternative to soybean seeds.

It is estimated that on a deep soil with high water resources, an orchard at 200 trees/ha may produce about 2 ton of pod dry matter at age 10 years (Dupraz and Newman 1997). Trees show an alternate bearing pattern and some varieties are in opposite phases, making a mixture of clones necessary to achieve sustained yields. More research is needed though to identify soft seed varieties of Gleditsia, to develop easy and cheap vegetative propagation techniques and to confirm productive data.

Arbutus unedo (Strawberry tree)
This tree from southern Europe has proven to grow and crop very well in temperate regions and produces edible fruits (PFAF 2004). The tree is very ornamental; it stays green year-round and in autumn and early winter its dense mass of greenery is mingled with a profusion of white flower clusters and red round fruits resembling small strawberries. The fruit remains on the tree for twelve months, not maturing until the autumn succeeding that in which the flower is produced (Botanical.com 2004). When fully ripe it falls from the tree and so it is advisable to grow the plant in short grass in order to cushion the fall of the fruit (PFAF 2004). This makes the trees most suitable in silvopastoral systems. Its beauty makes this tree especially attractive for recreational purposes. Dwarf varieties are also available. The plant prefers light (sandy) and medium (loamy) soils ranging from acid to alkaline, requires well-drained soil and can grow in heavy clay soil. It also grows in semi-shade and could thus also be used in the lower storey. The plant can tolerate strong winds and maritime exposure (PFAF 2004). Meredith (2002) notes it grows well on the British coast, but not in the colder parts of the country.

Caragana arborescens (Siberian pea tree)
This leguminous tree is said to have potential to become a staple food crop for its nutritious and wholesome seeds. Although the seed is rather small it is often very freely borne and is easily harvested. Furthermore it is a very ornamental plant and is noted to attract wildlife. The tree or shrub grows up to 6 m at a fast rate and can also be grown as a hedge. It grows well in most well-drained soils, preferring full sun and a light sandy dry or well-drained soil. It tolerates very alkaline soils, drought and even succeeds on marginal land (PFAF 2004). It has an extensive root system. This tough tree may especially be a good alternative for agroforestry systems on sites where other trees are hard to grow. C. boisii and C. fruticosa are closely related to this species and can probably be used similarly.
**Cydonia vulgaris** *(Quince)*
This is an up to 5 m. tall tree with fruits like hard yellow pears. The fruits are very fragrant and are commonly used to make jelly. Its is a good source of pectin. Quinces were once grown quite extensively in N-America and Europe, but pest problems limit their use today. Quinces prefer a fertile site in full sun. They should be planted in a protected environment because they respond poorly to rapid changes in temperature and exposure (Hart 1996).

**Juniperus communis** *(Juniper)*
The only native Dutch conifer is primarily grown for its berries, which have an essential oil of medicinal value. This is an easily grown plant, which succeeds in most soils so long as they are well drained, preferring a neutral or slightly alkaline soil. Grows well in heavy clays and poor soils and is tolerant to drought. It tolerates some shade, but grows best in sunny conditions (PFAF 2004). Being a native conifer, juniper could be a good option for semi natural agroforestry systems on soils, where other trees will not grow.

**Morus spp.** *(Mulberry)*
This tree used to be the “king of the tree crops”. *Morus rubra* originates from the USA, *M. nigra* and *M. alba* from Central Asia. It grows up to 6-15 m. After some years it gives good crops of luscious fruit like large raspberries, which can be eaten fresh or made into jam, jelly or wine (PFAF 2004). The fruits are soft and fall of the tree when ripe. They should be gathered by covering the ground and shaking the tree. Their softness and uneven ripening make them unattractive for large-scale cultivation, but it may well be a good tree for the development of specialty or regional products with added value. In China mulberry is traditionally cultivated in agroforestry systems (Huang 1998). They prefer deep open sandy soils and need moderate moisture, but even do surprisingly well on a wide range of adverse soil conditions (Eames-Sheavly 2001). They perform best in full sun, but will tolerate part shade. The root system is superficial and widely spread. Huese (2000) suggests that the mulberry could be a good natural trellis for grapevines in forest gardens.

**Amelanchier spp.** *(Juneberries)*
More than 25 species of juneberries are native to N-America. They grow up to 8 m tall and produce small juicy fruits that are commonly used in pies and preserves. They prefer full sun and acidic well drained soil, but they will tolerate shade and a wide range of soils (Eames-Sheavly 2001).

**Cornus spp.** *(Dogwood)*
There are various species in these genus that produce wonderful fruits. Some of the most promising species are described below and in Section 5.3.2.

*C. kousa (chinensis)*, the Japanese dogwood grows up to 10 m and is a very ornamental tree. Its fruits are the size of very large strawberries and have a succulent flesh with an exquisite flavor. The skin is fairly soft and can be eaten with the fruit, but it does have a decidedly bitter flavor (Meredith 2002). It grows in most soils, but prefers a rich well-drained loamy soil and a position that is at least partially sunny (PFAF 2004).
4.4.2 Lower storey trees

_Malus pumila_ (Crabapple)
Crabapples are short, neat trees, which are very suitable for the low tree layer of a forest garden (Hart 1996). They are first class pollinators of ordinary apples. Since they can give good yields and some of them are highly palatable, this may be a good candidate to produce for the niche market.
It is an easily grown plant, which succeeds in most fertile soils, preferring a moisture retentive well-drained loamy soil. It also grows well in heavy clay soils (PFAF 2004).

_Crataegus_ spp. (Hawthorns)
The hawthorns are adaptable small trees and shrubs, of which the fruits are commonly eaten in many countries. They have little demands on behalf of the soils, but optimum growth is attained on nutrient- and calcium rich, loamy soils.
Crataegus roots very superficially, making it vulnerable for heavy wind when grown as a tree. Grown as shrubs they are little susceptible. This rooting pattern may also imply a certain limitation to their combination with shallow rooting intercrops. It grows both in sun and light shade and as such would be well suited as a layer under higher trees (Janson 1989). The Dutch hawthorn (_Crataegus oxyacantha_) only produces small inedible fruits, but many foreign _Crataegus_ species form larger edible fruits. One of the best is the Mediterranean Azerole (_Crataegus azerolus_), a small tree with comparatively large yellow or pinkish fruits shaped like miniature apples (Hart 1996). For extensive info on various _Crataegus_ species, see PFAF (2004).

_Elaeagnus_ spp.
This is a genus of wind-hardy silvery shrubs or small trees related to the olives. _E. angustifolia_, _E. parviflora_ and _E. multiflora_ all have edible fruits. _E. umbellata_ forms small red or orange berries which taste like red currants. Hart (1996) claims this species is shade-tolerant and additionally fixes nitrogen, making it very interesting for inclusion in agroforestry systems. PFAF (2004) however note that _Elaeagnus_ species cannot grow in the shade. _Elaeagnus_ species grow well in most soils that are well-drained. They prefer a soil that is only moderately fertile, succeeding in very poor soils and in dry soils. They are very hardy and very tolerant to maritime exposure.

_Aronia_ spp. (Chokeberries)
Chokeberries originate from the eatern half of North America. _Aronia_'s are small trees growing up to 4 m. They grow in most soils, if well drained and can grow in the sun or in half-shade (PFAF 2004). The purple fruited chokeberry (_Aronia x prunifolia_) is being cultivated in the Northern Netherlands and juice, jam and syrup are marketed as regional products (waddenproducten 2004).

_Hippophae_ spp. (Buckthorn)
This genus includes some very usefull species. Two species with major potential for agroforestry are described below.

Sea buckthorn (_Hippophae rhamnoides_) is a shrub species, which grows up to 6m and is indigenous to the Netherlands. It forms small berries rich in provitamin A and vitamin C, which are said to give strength and reinforcement. They can be readily eaten, but are mostly
made into juices, jams, syrup, liquor or as additives to ice-cream and milkshakes. Branches with the orange berries are favorite in ornamental flower pieces. Fruits, leaves and branches are used to make medicinal oils. This crop is already cultivated on a commercial scale and marketed as a regional product in the coastal region of the North of Holland (waddenproducten 2004).

It grows on most soils so long as they are not too dry (PFAF 2004), but best on open and deep sands or loams. It grows well by water and in fairly wet soils and is resistant to maritime exposure. They cannot grow in shade. They form a strong taproot and fix atmospheric nitrogen, which makes them very suitable for agroforestry systems. A further advantage is that the market for products of sea buckthorn is already partly developed.

*Hippophae salicifolia*, the willow-leaved sea buckthorn, is a vigorous large deciduous shrub that suckers freely and so is not suitable for places where space is limited. It has similar demands and qualities as *H. rhamnoides*. Recent research has shown that this plant produces the most nutritious fruit yet discovered in temperate zones, regular use can prevent cancer whilst large quantities have been shown to reverse the growth of cancer tumors (Meredith 2002).

*Cornus mas* (Cornelian cherry)
This is a small, 5-6 m tall tree, that produces olive-sized fruit that can be used in jellies, tarts and sweetmeats. It produces yellow flowers in midwinter and is particularly attractive at this time.

It grows in full sun and partial shade and can be planted in shady areas under big trees. It prefers fertile, well drained soils, but tolerates a wide range of soils. It is usually pest-free (Eames-Sheavly 2001).

**Woody decorative florals**
Many woody plant species that have a colorful or unusual shaped stem, bud, flower, leaf or fruit can be used for decorative floral product. Examples are: cultivars of yellow- and redstemmed dogwood (*Cornus* spp.), many kinds of willows (especially curly and pussy willow, *Salix* spp.), red birch (*Betula lenta*), flowering branches of forsythia (*Forsythia* spp.), witchhazel (*Hamamelis* spp.). Also flowering branches of previously mentioned species, such as apple, plum, cherry, and fruiting branches of Sea buckthorn (*Hippophae rhamnoides*), are valuable for this purpose. Cuttings from coniferous trees have potential as floral greens.

Ornamental branches may be obtained when pruning tall trees. However, as good opportunities exist to obtain substantial returns by producing and marketing such decorative woody stems (e.g. Hill and Buck 2000), it should also be considered to plant shrubs and trees especially for this purpose, e.g. planted in the tree rows under taller trees or as a coppice intercrop.

### 4.5 Conclusions

There is a large variety of tree species with potential for temperate agroforestry. In this chapter it was tried to give an impression of the range of possible species for application in Dutch agroforestry systems. It was not tried here to identify the “best species”, since the agroforester’s choice for a certain tree species is dependent on a many factors, such as the site-characteristics, intercrop species, farm-management and -objectives (Chapter 8).
A survey among Dutch farmers’ and estate owners’ about their attitude towards agroforestry revealed that a preference is given to trees that provide income on the short term, especially in the form of fruits/nuts (Chapter 7). It must not be forgotten however, that also fruit trees will take 5-10 years to yield fruits. The well known species walnut, hazel and chestnut provide marketable products without difficulty and are suitable for application on highly mechanized farms. Other species may be more labour intensive, but yield specialty products and may thus suit best for small scale farms. Fast growing trees as poplar may, in favorable conditions, produce marketable wood in less then 25 years.

However, it must be understood that landowners with affection or trust in (agro)forestry, may also be interested in growing trees that in the end will give good returns, but need a mid-term investment up to 40/50 years. Landowners with the prime aim of producing quality wood on a mid-term, have the choice of a great variety of trees species, some of which, such as poplar, cherry, maple and ash, show great potential for agroforestry applications. Also species as Sorbus domestica, S. torminalis and Pyrus communis seem promising for wood production in agroforestry systems, but have not yet been researched for top-grade planting material (Dupraz and Newman 1997). For extensive information on the current recommended varieties and provenances of trees, referred is to the 7th list of tree races (CRB 2002).

According to Kuipers (pers. comm. 2003, Stichting Bos en Hout, Wageningen), the most interesting timber tree species for agroforestry in the Netherlands are poplar, walnut and wild cherry. Most information on silvoarable agroforestry in Europe concerns the use of deciduous trees, mainly because the emphasis is placed on light demanding row crops as intercrop species. However for silvipastoral systems and silvoarable systems with alternative intercrops, such as shade-tolerant specialty crops, forages and horticultural species, conifers may also be suitable.
5. Intercrops for temperate agroforestry systems, in particular the Netherlands

5.1 Introduction

An agroforestry system will comprise at least one layer of intercrops, e.g. a layer of pasture or cereals in silvopastoral or silvoarable systems respectively, but may also consist of two or more layers, up to seven layers of intercrops in complex forest gardening systems (Section 2.4.3).

Choosing intercrop species, one can use comparable criteria as for the tree species:

1 the intercrop is economically profitable in the relatively short term
2 the intercrop is adapted to the local circumstances
3 the intercrop is compatible with a tree component (preferably with positive interaction)

As explained in Section 3.3.1, a major constraint for temperate agroforestry systems is the amount of radiation available for the intercrop. In tropical regions, the strong light conditions allow even under storey layers in multi-strata systems to receive substantial light, whereas in temperate regions this is not the case (Hill and Buck 2000). Therefore, in the Netherlands, the agroforestry intercrop must be chosen very carefully considering light conditions, which depend on tree species, tree size and system design. During the first 3 to 7 years of an agroforestry system the tree shade effect is negligible (Section 5.2). In a later stage however, decreasing light conditions may constrain the growth and ripening of light demanding intercrops. To maintain a profitable agroforestry system and to optimize the LER (land equivalent ratio), chosen could be for tree thinning, tree pruning, increasing the tree-crop distance or choosing for shade-tolerant or shade-demanding intercrops. There are plenty of crops which tolerate shady conditions, but many are not well known.

The possible intercrops for inclusion in agroforestry systems can be roughly divided into four groups: conventional “bulk production” food- and forage crops (cereals, maize, potatoes, beets, grass and vegetables), smallfruit, specialty crops and non food crops for fiber and biomass production. In the following chapter, these crop groups will be described including their qualities and growth requirements, which indicate their potential and their possible role in agroforestry systems. Where possible, an analysis will be made of the experiences regarding the inclusion of the various groups and/or species in agroforestry systems.

5.2 Conventional agricultural crops

5.2.1 Cereals, maize, potatoes, sugarbeets and fodderbeets

When we consider silvoarable agroforestry as wide spaced tree rows on an arable field and if the distance between tree trunk and crop field is 0.5 to 1 meter, it can be expected that there will be little or no competition-effects between the trees and intercrop for the first years after tree planting and in principle it should thus be possible to cultivate almost any conventional crop as intercrop during the initial years of tree establishment. Data available so far indicate that little if any yield reduction of crops was observed during the first 5 to 7 years in silvoarable systems with slow growing high quality hardwoods, such as walnut or wild cherry (Garrett and McGraw 2000, Dupraz and Newman 1997, Nair 1993). This is particularly true for winter crops (Mayus pers. comm. 2004, Crop and Weed Ecology Group, Wageningen). In
The development of tree canopy and crop growth are more synchronous and thus yield reduction should be more important. Moreover, with increasing tree density, yield reductions due to shade and eventual below ground competition will occur earlier within the agroforestry life cycle. The latter is true also for trees with large and dense canopies as that of poplar. With poplar, the outcomes of various investigations varied considerably, possibly due to different tree densities. Newman (1994) found dramatic decreases in cereal yield at age five, but no significant yield decrease at the age of three in one experiment, while in another experiment no yield decreases of wheat was noticed at 6 years age (Newman 1994). Dupraz and Newman (1997) report about a silvoarable system practiced by a British company in the 1950’s. The alleys between the rows of poplar in this system were cropped successfully with cereals for 8 years and the last cereal was undersown with a grass-clover mixture.

In an experiment in the Netherlands (Edelenbosch 1994) little or no yield decrease was noticed for sugarbeets and maize in the first 2-3 years at 202 poplars/ha (4.5 x 11 m), while at age 4 the yield decrease was about 20 %, making for still a profitable intercrop. Poplars did show a decreased growth though: 10-15 % in dbh (diameter at breast height) and 4-5 % in height, equaling less than half a growth season. In another experiment (Swellengrebel 1990) with poplar at 3 x 3 m and an intercrop of fodderbeet, the loss of the non-cropped tree strips (28 % of the surface) was roughly compensated by clearly visible better growth of the beets bordering the tree-lines. This is probably primarily caused by the bigger growth-space of those beets, but maybe also by the shelter of the trees. Beets were intercropped for three years and no yield reduction was measured.

Garrett and McGraw (2000) and Nair (1993) give numerous examples of intercropping practices during the first years of tree establishment in orchards and plantations in many different temperate countries, for instance with corn, soybean, milo, wheat, barley, oat, potato and other tuber crops. Dupraz and Newman (1997) mention that in the French walnut production area of Dauphine 20 % of the walnut orchards are intercropped with conventional crops as maize, winter cereals (durum wheat, wheat, barley), sunflowers, canola (Brassica napus) and tobacco. 80 % of the orchards aged 10 years or less. They also mention that in Dauphine short intercrops are often preferred to maize, which allows better ventilation of the tree canopy and reduces the impact of diseases on the foliage. This may indicate that maize and other high and dense growing crops may not be ideal intercrops for walnut and maybe for other slow growing trees. They may well combine with fast growing species as poplar though, considering the good experiences with maize-poplar intercropping, at least in the first years of poplar establishment (Edelenbosch 1994, Dupraz and Newman 1997).

Research on modern temperate silvoarable agroforestry is still in an early phase. This and the fact that the agroforestry design, species and circumstances in agroforestry experiments with conventional crops are rather heterogeneous, makes it is difficult to make clear-cut statements on which crops are most suitable in later phases in the development of the agroforestry system, when competition effects will become stronger. As mentioned earlier, there are several investigations that have shown that cereals are still able to grow as an intercrop after 6-8 years. There are examples of 20-25 year old walnut orchards intercropped with soybean and cereals in France (SAFE 2004). These examples suggest that at least cereals will not quickly suffer from a little shade and may be maintained as an intercrop for quite a long period. Winter cereals have the particular advantage of being able to establish themselves when the trees are leafless and in rest, which means little above- and belowground competition.

The main advantage of cereals and maize over potatoes and beets is that they demand relatively few machinery runs (for weeding and spraying). As explained in Section 3.3.3, tree rows will often mean a lower efficiency with the machinery and more labor. Consequently potatoes and beets will cost even more labour and will decrease the net returns of these
crops in agroforestry. More machinery runs will increase the chance to damage stems and branches with the machinery and the harvesting of root crops will mean a higher chance of damaging tree roots. Additionally, potatoes and beets are often harvested with a car next to the harvesting equipment, which will mean the necessity of a clear strip next to the crop to allow for the car. This would mean a clear strip of about 3 m next to each tree-row, making the system very inefficient. However, with a combiner-harvester this problem does not exist. Potatoes are also known to produce much less under influence of tree plantings. Windbreaks however, are known to increase yields and sugar-production of sugarbeets due to the better microclimate (Boer en Oosterbaan 2004).

5.2.2 Vegetables

In general the same count for vegetables as for the crops mentioned above: intercropping practices of vegetables in the first years of orchard establishment indicate that no growth reduction are expected in the first up to ten years as long as the tree crowns are open enough to permit enough sunlight to reach the vegetables. Nair (1993) gives various examples of intercropping fruit orchards with vegetables and notes that in Washington State approximately 10 % of fruit orchards are intercropped with vegetables, mostly for home use.

The advantage over the crops mentioned above is that the open structure and the rooting pattern of certain vegetables may mean less competition for nutrient and water. Although common vegetables will not thrive in full shade, certain species are known to withstand some shade, for instance endive, beet-root, peas, runner- and faba-beans, radish, spinach, sprouts, rhubarb, lettuce, cabbages (PFAF 2004, faq van NL.tuinen 2003). In general leafy vegetables are supposed to be quite shade-tolerant and may even benefit from some shade.

Winter- and spring vegetables have the advantage of growing in the period when the trees show least competition for light, water and nutrients. Vegetables as kale, winter carrots, winter salads, and early cabbages, spinach and radish may thus have good potential for intercropping.

5.2.3 Pasture and forage

5.2.3.1 General

In temperate zones, grass is often considered as one of the most economic intercrops in aged agroforestry systems, where shade makes the cultivation of conventional crops uneconomic. Combinations of high-stem fruit trees with low densities per hectare intercropped with grass and grazed by livestock were once very common in the Netherlands, especially in the Betuwe between the rivers Maas en Waal and in Zuid-Limburg. The improved efficiency in fruit-growing through the introduction of short-stem cultivars, which are planted at high densities, has resulted in virtual disappearance of highstem orchards (Gijsbers 1994). In the Netherlands, in 1945 several ten thousands of hectares of high-stem orchards existed, while nowadays only 1000 hectares of high-stem orchards are left in the province Gelderland and about 700 hectares in the province Utrecht and Zuid-Holland (LETS Utrecht 2004).

Grass is expected to grow without reduction for the first 7 to 10 years in agroforestry systems (Newman and Adams 1997, Oosterbaan et al. 2001). Clason and Sharrow (2000) mention that trees have little impact upon forage production until their combined canopy cover exceeds 35 %. Forage yields tend to drop off quickly as canopy cover and tree basal area increase above that value. In an agroforestry experiment in the Netherlands with poplar and
grass (Edelenbosch 1994) little or no yield decrease was found for grass at age 4 at 404 trees/ha (4.5 m x 5.5 m). With the grass intercrop, the poplars did show a decreased growth of 30 % at DBH (diameter at breast height) and 10 % in height, comparable with the growth in one growth season.

Some grass species may fit better in agroforestry systems than others. Certain shade tolerant grasses are even able to grow under a full tree cover (Garrett and Harper 1999, Gordon and Williams 1988, Oosterbaan et al. 2001). Oosterbaan et al. (2001) make notice of studies, which suggest that the shade tolerant species Agrostis tenuis and Dactylis glomerata are most suitable for silvopastoral systems with pine trees. In Missouri, Garrett and Harper (1999) found that Dactylis glomerata, Bromus inermis, Festuca arundinacea, Agrostis gigantea and Phalaris arundinacea were most shade tolerant.

In the Netherlands, Bakker (1960) found that Agrostis tenuis, A. stolonifera and Dactylis glomerata strongly preferred the border strips along poplar plantings. High-quality grasses such as Lolium perenne, Festuca pratensis, and Poa trivialis could easily maintain themselves among grasses of lower quality in the border regions, probably owing to its excellent fertility.

In a sowing experiment of a 25-year old poplar plantings (9 m x 9 m) with different grass-mixtures, Bakker (1960) found that Dactylis glomerata maintained itself well. The percentage Poa trivialis remarkably increased, probably caused by high soil-nitrogen contents. The valuable grass species Lolium perenne and Festuca pratensis decreased their share. This decrease was only slow however, indicating that L. perenne and F. pratensis have a high tolerance to shady conditions as compared to Poa pratensis, Phleum pratense and Trifolium repens (white clover), which could hardly maintain themselves in the mixture. Bakker recommended a mixture of mainly good grasses as Lolium perenne, Festuca pratensis, Poa trivialis and a small amount of selected Dactylis glomerata (22.7, 6.5 kg/ha respectively) for sowing poplar pastures.

It can be concluded that high quality grasses can be grown without considerable production losses as an intercrop in the first 10 years of an agroforestry systems, depending on the tree density. Although valuable grass species are able to maintain for longer periods under trees, with increasing crown cover and thus increasing shade, the species composition will gradually shift to more shade tolerant grass species, which are usually of a lower quality (Oosterbaan et al. 2001). Sharrow (1997) on the other hand, mentions that forage grasses under shady, low wind environment near trees tend to mature more slowly. As a consequence they have a lower fibre content and are more digestible compared to forage species growing in the open.

It should be taken into account that trees may also suffer from competition with dense grass swards for nutrients and water. The ability of plants to withdraw soil moisture and nutrients is strongly associated with the amount of fine roots that they have. Ground vegetation that quickly establishes a dense, shallow, fibrous root system, such as many perennial forages, competes severely with newly planted trees. Young, establishing trees may be killed by drought stress in thick stands of ground vegetation, but substantial reduction in tree growth is more common than actual mortality. Dense stands of brush may reduce the growth of even established trees. Underground competition is particularly harmful for young multipurpose trees that are to produce fruit, since good growth during the first years of establishment are crucial for later fruit production. In a later stage the inhibiting effect of grass on wood growth in certain fruit trees could be useful, i.e. after the tree has attained a sufficient size and profit is more dependent on reproductive (fruit) than vegetative (wood) growth (Dupraz and Newman 1997).

A solution for underground competition may be to start with intercrops that are less competitive and introduce forage at a later stage when tree root systems have well
developed. Dupraz and Newman (1997) make notice of the work of A.H. Hoare, who already wrote on orchard intercropping in 1928 and saw great potential for successional planting and cropping of sweet cherries with vegetables, strawberries, fruit bushes and then finally grassed down with the correct grass species to be grazed by sheep or poultry. When planted on already established pastures, young trees will benefit from two to three years of vegetation control after planting. A commonly used approach when planting trees into established pastures is to spray a strip or circle around trees to provide a one to two meter diameter competition-free zone around each tree (Sharrow 1997).

In silvopastoral agroforestry systems one can choose to let livestock graze the strips of pasture, to mow for hay or silage or a combination of both. Both have their own specific advantages, disadvantages and problems, which will be treated in the chapters below.

5.2.3.2 Forage production for hay or silage
The advantage of hay or silage production is that no expensive fencing or protection is needed to avoid trees being damaged by livestock. In forested regions however, it may remain necessary to fence the agroforestry plot to protect young trees from browsing by wild animals such as deer. When one makes the choice for hay or silage, the agroforestry design must match the available machinery (i.e. the machinery must fit easily in between the rows). Furthermore one has to take into account the reduced efficiency, compared to treeless forages. The work will take longer, since one has to circle around the trees and one will harvest a few percents less (Oosterbaan et al. 2004). Research of Oosterbaan et al. (2004) showed that a narrower spacing of trees (10 x 10 m) results in more tree damage and increasing costs of harvesting (more time needed per ha), as compared with wider a spacing (20 x 20 m).

Finally, the specific microclimate invoked by the presence of trees (shade, decreased wind circulation), especially with close spacing and high crown-cover could increase the drying period of mown grass. The latter complicates the hay making. Silage might be an alternative.

5.2.3.3 Pasture
Sheep, goats, cattle and horses
In pastures, trees provide shelter for livestock, especially during periods of inclement weather. This can significantly improve animal performance during particularly hot or cold times of the year. As such trees contribute to the well-being of the livestock, which in return may lead to an economic benefit (Section 3.2.2).

Grazing animals are known to be able to severely damage young trees by trampling, browsing and debarking, if not well protected. Age and experience of animals is probably more important than breed in predicting the willingness of livestock to browse or debark trees. Young animals and those with a past experience of eating tree foliage are much more likely to browse trees (Sharrow 1997). Goats will generally consume more browse than will cattle or sheep and are generally more difficult to graze among young trees (Clason and Sharrow 2000). Hawke and Knowles (1997) mention that livestock can be ‘trained’ to graze among trees. Livestock not accustomed to trees usually cause initial damage, but such damage declines with regular grazing. Browsing damage can sometimes be eliminated by removing a few problem animals. Browsing by livestock is unlikely to kill young trees unless it is both severe and repeated several times.

Since deciduous species are more palatable than pine trees, these will be more vulnerable to browsing. To get valuable timber wood it will be necessary to get straight logs and hence it will be necessary to protect trees during the establishment phase. Once the top branches of trees grow above the reach of livestock and a thick layer of bark has developed, potential for
Tree damage by livestock browsing is minimal and agroforests may be managed similar to pastures (Sharrow 1997).

It is possible to protect young silvopastural trees from livestock by means of fencing, electric wire or individual tree shelters. Other options are to cut hay/silage or to grow crops until the trees are well established and introduce livestock as soon as the trees are well established.

In the last 15 years plastic tube-like tree shelters have gained wide acceptance in France and the UK, but the experiences with these are not always good. Reduced growth and poor form in trees when they emerge from the shelter are some of the reported problems (Dupraz and Newman 1997). Improvement of shelter have partly solved this problem. However, tree protection remains expensive and may cost more than the value obtained from the increased grazing. Nonetheless the hindrances mentioned, most of the ‘trees on pasture’ plantations in Europe have been made possible through the use of such shelters (Dupraz and Newman 1997).

When one has the choice though, it will probably be more cost-effective to only introduce grazing animals after a couple of years, when trees are well established and are grown well above the height of the livestock. Slow growing species and species with thin and palatable bark, such as cherry, are more sensitive for damage and will need a longer protection than more robust trees. Repellents or an abrasive paint-on applied to the tree stem may also be effective to avoid tree debarking (Dupraz and Newman 1997, Williams et al. 1997).

Nair (1993) indicates that even in early years in pine plantations, livestock may be allowed to graze during seasons when the nonconifer vegetation is more palatable than tree seedlings. In general livestock should be removed as soon as fodder becomes short, to prevent bark damage to the trees (Clason and Sharrow 2000, Sharrow 1997)

Poultry, pigs, deer

More and more people nowadays are choosing free range or biological eggs and (to a lesser extent) meat. This expanding market may be an interesting option for agroforestry.

Chickens originate from forest species and thus feel best in such environment. Evidence suggests that our modern poultry breeds still prefer tree/shrub cover to the open grass ranges currently favored by farmers. Certified free range meat chickens are provided with at least 1 m² surface in the open air each. Certain types of free range hens and all biological poultry are given 4 m² each at least (Biologica, 2004). However, in existing free range poultry systems, chickens appear to be reluctant to range, even when the very best ranging conditions are provided (artificial shelters, fences, hedges etc.). In a recent study, no more than 14% of chickens were observed to leave the house at any one time (Northmore trust, 2004). In the UK, very recently various projects are set up with agroforestry systems for chicken production (Northmore trust, 2004, Philipps et al. 2002). It is expected that the woodland environment will encourage ranging and more natural behaviour and thus lead to an overall benefit in poultry welfare. Commercial performance of the birds may be improved as a result of this welfare enhancement. Additionally herbs could provide nutrition and medicinal benefits for them. The environment should offer the poultry increased protection from aerial predators, so either high density plantings or established agroforestry systems where tree crowns are at least partly closed.

The presence of poultry will also have advantages for the trees. Competing undercover will be controlled, reducing the need for herbicides and manual input and tree growth will be improved by fertilization from poultry manure. Furthermore poultry may help in insect control and will clean fallen fruits, nuts and other organic wastes. Poultry will not damage the trees, so expensive tree protection will not be necessary.
Although few examples of such practices are found in temperate regions nowadays, it is likely that other free range animals for meat-production can be introduced in agroforestry systems. Pig, turkey and deer are all forest species in nature and will, thus, benefit from trees in their free range area. In Spain and Portugal, pigs are commonly kept in extensive agroforestry systems with cork-oaks, where they feed on the acorns (Dupraz and Newman 1997). The pig meat from this system has a special flavor which is highly valued and makes a good price on the market. In Norway, the elm is traditionally used as a feed for livestock. In the past, acorns from the forest were used as pig feed in the Netherlands as well. Oaks however have an irregular pattern of fruit production and acorns are short in proteins, which makes them not the ideal feed. It may, however, remain valuable as an additional feed to obtain the special flavor. Honeylocust (Gleditsia triacanthos) has been proposed as a better species to produce feed for animals (Section 4.3.1). With this tree an integrated feed and meat production system may even be possible in the Netherlands.

### 5.3 Smallfruit

#### 5.3.1 General

Many berry species originate from the forest or forest-edge and may, being used to (partial) shade, have a good potential as intercrop. Nevertheless, for most berries a reasonable amount of sunlight must be available to ensure good fruit production. Gooseberries and currants perform good in partial shade, other small-fruit need at least six ours direct sun a day, preferably more (Eames-Sheavly et al. 2003).

The area of woody smallfruit in the Netherlands has strongly decreased since the 60’s, caused by the increased competition from Eastern Europe, in particular the production for processing industry. From 1979 Dutch production stabilized at about 500 ha spread over the country, mainly for fresh consumption. An exception form the black currant and the blue berry, which are mechanically harvested. Most other berries are cultivated on small areas on small farms, making mechanization and cultivation measures suboptimal (NFO 1990).

For the marketing of fresh fruits, it is important to strive for an optimal spread of harvest. Outside the traditional harvesting season, best prices are paid for the product. Farmers can adapt to this by choosing the right cultivars. This is a better solution than the cultivation in plastic tunnels to accelerate or delay harvest, which is accompanied with problematic crop protection.

Almost all races of woody smallfruit are vulnerable for various diseases, while only a limited array of pesticides is permitted. The fungus botrytis can cause severe damage to all small-fruit crops. Root disease, caused by Phytophthora megaspora is a big problem with raspberries. Maybe a more natural cultivation under agroforestry will decrease disease pressure and thereby minimize the harvest risks of woody small-fruits.

#### 5.3.2 Well known species

**Vaccinium spp.**

The heigh bush blueberry (*Vaccinium corymbosum*) and cranberry (*Vaccinium macrocarpon*) originate form N-America. The bilberry (*Vaccinium myrtillus*) is an indigenous species in the Netherlands. Cranberry and bilberry stay low and can form a good groundcover. Heigh bush blueberry grows up to 2 m high. Their fruits are rich in vitamin C, they can be eaten raw or cooked and used in pies, pastries, cereals and jellies. They can also be dried.
All three species thrive on poor acid peaty soils and can grow both in sun and in half shade (Huese 2000), but they fruit better in a sunny position though (PFAF 2004). The need for acid peaty soils limits their combination with trees in agroforestry systems. Although these species could be grown in association with pine trees on peaty soils, most multipurpose or short rotation trees mentioned in Chapter 4 will not grow well on acid peaty soils.

Ribes spp.
The genus comprises gooseberries (Ribes grossularia, R. hirtellum, R. uva-crispa), black (Ribes nigrum), red and white currants (Ribes rubrum) and worcesterberries (Ribes divaricatum). The jostaberry, a cross between the gooseberry and black currant has also proven its value; it has the fastest growth of all species, is resistant to various berry diseases and yields 5-8 kg of big black fruits per shrub.

This genus is probably one of the best for the shady lower storey of temperate agroforestry systems, since they are woodland plants in their native state. Good experience has been reported on their cultivation under trees. Hart (1996) reports that a traditional form of agroforestry practiced in the Fen area of Eastern England has been the growing of gooseberries in orchards. There are many varieties of gooseberries available, but for the forest garden he specially recommends “Whinhan’s Industry”, as it is specially shade-tolerant. Possibly old races are more shade-tolerant than modern varieties.

Also black currants are traditionally found in agroforestry systems in the British West Country, being interplanted with plums. Shoemaker (1955) mentions that currants and gooseberries are sometimes used as intercrop in intensive orchard systems. The shade is of some benefit, particularly to the gooseberry. He writes “where trees are set 20 feet apart there is room for only one bush between each pair of trees and it is questionable whether there is enough space between tree rows for a row of cane fruit. At greater distances, about 24 feet, there would be enough room for 2 bushes between each pair of trees and also for a full row of cane fruits between the rows of trees. At larger distances, more of the cane fruits can be set both in and between rows”.

Gooseberries and currants grow on a variety of soils, but they prefer fertile airy humus rich soils that can hold sufficient moisture. Sites with poor air-circulation, which increases the incidence of powdery mildew, should be avoided. For gooseberries, races that are more resistant to American mildew have come available, which offers good opportunities for its cultivation in agroforestry systems. Fresh consumption of red and black currants have increased in recent years, indicating that there is a market for such products.

Rubus spp.
Raspberry, blackberry and Japanese wineberry (Rubus phoenicolasius) are the most cultivated species of this family. The first two are indigenous species, the Japanese wineberry originates from E-Asia. All berries can be grown as hedges of 1.5-2 m high (Neerlands tuin, 2004).

Both raspberries and blackberries like fertile soils. Raspberries prefer humus rich soils or calcium rich clay with humus added. Fertilization is not necessary, since the more nitrogen, the less taste and the harder to keep them fresh. Compost is best. Blackberries prefer high N-gifts and humus rich moist soils. On shady places they flower bad and yields are low. Furthermore the taste is less or the berries will hardly ripen. They will thus grow best in young agroforestry systems or on the southern side of tree rows. The Japanese wineberry looks like the blackberry, but grows less wild and is good to lead. It is an easy shrub, which hardly knows diseases. It needs a place in the sun or half shade and grows on all soils, preferably humus-and calcium rich.
5.3.2 Less known species with potential

There are various temperate berry species that may have potential for the Netherlands. Most of these will have potential for small scale cultivation only, and for sale on regional markets, delicacy shops or restaurants. Their real market potential should be further explored and developed in the Netherlands.

Actidinia spp. (Kiwi fruit)

Actidinia species are fruiting climbers from China and elsewhere in the Far East. The “Chinese Gooseberry” is most commonly eaten in the west as kiwi-fruit. Since they are climbers, they will need to be trellised for easy picking. In China, Actidinia species are multi-purpose plants. Oil can be extracted from the seeds, the leaves are rich in starch, the roots are used medicinally, the fibers are used in paper-making and the abundant resin is used for dyes and plastics (Hart 1996).

The commercially available kiwi is probably not the best Actidinia for the Dutch climate, because of its cold-tenderness and long growing season. A cousin of this kiwi, though, the hardy kiwi (Actidinia arguta), originates from Siberia and is much more cold hardy. This species has interesting properties such as its good flavor, relatively smooth (and edible) skin and “out of hand” eating size (about the size of a large grape). In temperate regions in France and the USA, commercial plantations have been established already, but the growing of hardy kiwi remains an experiment (Pennsylvania State University 2001). The small fruit size, limited ripening period and shorter shelf life are market limitations and have so far kept acreage limited in France (Strik and Cahn 2000). Cultivar development is in its infancy, because of the newness of this crop, but some cultivars of the hardy kiwi are available.

Although very hardy, the hardy kiwi is susceptible to late frost. Vines perform best in full sun, but on such sites they tend to break dormancy too early in the spring, when late frost can damage new growth. Eames-sheavly et al. (2003) therefore recommend a Northern exposure to delay early growth and minimize these risks. The succulent growth furthermore is susceptible to wind damage and hot, dry conditions. Protected moderate microclimates are best, as the kiwi does not like sudden temperature changes. These properties seem to make the hardy kiwi especially suitable for temperate agroforestry systems.

Kiwi fruit grows on all soils with a pH between 5.5 and 7. It thrives in moist soils, but does not tolerate poorly drained soils. It benefits from the incorporation of organic matter before planting. There are some important horticultural limitations on the cultivation of hardy kiwi’s though. Actidinia’s are dioecious, so both males and females must be planted to get fruit. Furthermore the plants often take several years to mature, and usually do not bear fruit until they are 5 to 9 years old. Finally hardy kiwi are extremely vigorously growing vines, requiring a substantial supporting trellis, otherwise they will grow up the trees (Pennsylvania State University, 2001).

Elaborate information on cultivation is available from Strik and Cahn (2000).

Gaultheria hispidula and G. humifisa (Creeping snowberry and Alpine wintergreen)

These two species from N-America, closely related to the Vaccinium species, stay low and are a useful fast growing ground cover plant for shady places. The small fruits are eaten raw or cooked or can be made into preserves. Also the leaves can be eaten or used for tea (PFAF 2004). These plants prefer light (sandy) and medium (loamy) soils, which are acid or neutral and can grow in very acid soil. They grow well in semi-shade and require moist or wet soil. Just like Vaccinium, these plants like acid peaty and lime-free soils, which makes them most suitable for combination with pine trees.
Gaylussacia baccata (Black huckleberry)
Also this plant is a N-American relative to the Vaccinium species. It grows up to one meter high and its fruits are used raw, cooked, dried or made into pies and preserves. The plant grows on both sand, loam and clay soils, but prefers acid soils and can grow in very acid soil. It can grow in sun or semi-shade. It requires dry or moist soil that are well drained. For their preference for acid soils, they will combine best with pine trees. Also other species of Gaylussacia form edible fruits and may be useful in a similar way (PFAF 2004).

Myrica carolinensis (Bayberry)
This shrub (up to 3 m) from N-America gives edible fruits and leaves. The leaves are used as a condiment in dishes. The plant has medicinal properties as well. Furthermore a dye is obtained from the leaves and fruits and the wax on the fruits is extracted to make candles (PFAF 2004). It grows on lime-free loamy or peaty soils that are moderately moist to wet. It grows in sun and half shade (Huese 2000). The plant is very wind hardy and can be grown in hedges.

Cornus canadensis (Creeping dogwood)
Most Cornus species are trees that form small fruits (see 4.3.1). Especially suitable for agroforestry purposes seems Cornus canadensis from N-America. This beautiful creeper gets only 20 cm. tall and needs half shade to form a good groundcover. It is a very good dense ground cover plant and when established they can spread 60 - 90cm per year. The plant grows in most soils, if moist and can grow in heavy clay soil. The plant prefers acid and neutral soils (PFAF 2004).
In September/October it forms clusters with 4-7 long round berries, which are a delicacy. The fruit is rich in pectin and the Laps of Northern Scandinavia make them into a fruit-jelly which is used in pudding.

Viburnum trilobum, V. edule and V. opulus var. americana (Highbush cranberries)
These highly ornamental bushes grow up to several meters tall and can be made into hedges. The size and color of the fruit are the only similarities with normal cranberries. The fruits are rich in vitamin C, they are an excellent substitute for cranberries and are used in preserves, jams, jellies and sauces. The fruits are about 1 cm, showy red and very persistent, remaining on the bushes well after frost. Some authors mention that to avoid astringency, fruits are best harvested in summer or autumn (Eaves-Sheavly et al. 2003). Other sources note that fruits taste best after frost (PFAF 2004).
They perform well on a range of soils and can even grow on heavy clay. They tend to decline with too much moisture stress though and prefer a deep rich loamy soil in sun or semi-shade (PFAF 2004).

5.4 Specialty crops
Many specialty crops have a high potential as agroforestry intercrops, many even in shady conditions. Specialty crops automatically also means that specialty markets are necessary; often products are marketed only on a small scale or marketing channels may not even developed yet in the Netherlands. For many of these crops markets should be sought for in specialty shops, local restaurants or in the form of regional products.
5.4.1 Woody ornamentals

Conifers
Various coniferous species are well able to grow in partial shade. Especially the cultivation of Christmas trees may be a good option as one of the intercrops, or as temporary plantings in tree lines. A secondary advantage of such intercrop is that it will support a straight growth of the main tree species and prevent knots, resulting in valuable logs and decreased pruning costs. Planting in the tree line of fast growing species as poplar may be less suitable, as these will quickly cast too much shade, forcing the coniferous trees to make more open crowns (longer internodes) which makes them unsuitable as Christmas tree (Oosterbaan, pers.comm 2004, Alterra, Wageningen).

Bamboo
Many bamboo species could be grown in an agroforestry environment. They are ideal woodland plants and often prefer growing in a dappled shade. They are shallow rooted and hence are good to combine with deep rooting trees. An additional advantage of growing bamboo as an intercrop may be that they support the straight growth of the tree and decrease the necessity of pruning to get straight logs.

There are innumerable species and just as many uses of bamboos. The bamboo sticks can be used for supporting trees, making furniture, paper, construction, water tubes and many other utensils. The young shoots can be eaten and may have potential to be marketed as a specialty food in the Netherlands. Nice stalks and the whole plant can be marketed as ornamentals.

Although many species are suitable for the Dutch climatic conditions, probably the best all-rounder is the genus *Phyllostachys*, which produces the nicest and largest edible shoots and very good quality canes (Fern 1997). They usually prefer a moist soil.

For specific information on species habits and requirements referred is to Fern (2000) and PFAF (2004).

5.4.2 Herbaceous ornamentals

Ferns
Many ferns originate from moist and shady wooded environments and as such are excellent intercrops for established forests and older agroforestry systems when shade no longer permits other crops to grow. Ferns can be sold as whole plants or the leaves can be cut for use in ornamental pieces and bouquets.

Flower bulbs
Many ornamental bulbous species come from (partly) shaded forest environments. Most shade tolerant or shelter-demanding flower bulbs could be cultivated as intercrops as long as shade is not too dense. Some bulbs even demand shaded environments for good growth or have most of their growth in early spring when trees are still leafless. These species are especially suitable for integration in aged agroforestry systems when most crops are out shaded. Table 5.1 gives a selection of bulbous ornamentals with potential in agroforestry and their specific demand regarding light and soil.

It must be noted however that this list is not complete; probably many more bulbous species can be cultivated in agroforestry environments. Also the more conventional light demanding species may well fit in the early stages of agroforestry systems. Since most bulbous species
have a relatively small and superficial root system, it can be expected that these will cause rather low below ground competition with the tree.

Table 5.1: Growth requirements of flower bulb species with potential for AF

<table>
<thead>
<tr>
<th>Species</th>
<th>Growth place</th>
<th>Soil type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Allium spp. (ornamental onion)</td>
<td>Sun/half shade</td>
<td>All soils</td>
</tr>
<tr>
<td>Anemone spp.</td>
<td>Everywhere</td>
<td>Sand, sandy clay, clay</td>
</tr>
<tr>
<td>Arum italicum</td>
<td>Sun-half shade-shade</td>
<td>All soils</td>
</tr>
<tr>
<td>Camassia spp.</td>
<td>Everywhere</td>
<td>Sand, sandy-clay, clay</td>
</tr>
<tr>
<td>Chionodoxa spp.</td>
<td>Everywhere</td>
<td>All soils</td>
</tr>
<tr>
<td>Colchicum spp.</td>
<td>Everywhere</td>
<td>All soils</td>
</tr>
<tr>
<td>Corydalis cava, Corydalis solida (fumewort)</td>
<td>Halfshade</td>
<td>Sand, sandy clay, moist</td>
</tr>
<tr>
<td>Crocus spp.</td>
<td>Sun/half shade</td>
<td>All soils</td>
</tr>
<tr>
<td>Eranthis spp.</td>
<td>Sheltered (especially E. hyemalis under trees)</td>
<td>All soils (high O.M.)</td>
</tr>
<tr>
<td>Erythronium spp.</td>
<td>Sheltered from wind</td>
<td>Sand, sandy clay</td>
</tr>
<tr>
<td>Fritillaria meleagris</td>
<td>Half shade</td>
<td>All soils, humus-rich, moist</td>
</tr>
<tr>
<td>F. michailovskyi</td>
<td>Everywhere</td>
<td>All soils, moist</td>
</tr>
<tr>
<td>F. persica</td>
<td>Sheltered from the wind (length)</td>
<td>All soils</td>
</tr>
<tr>
<td>Iris danfordiae/reticulata</td>
<td>Sun/half shade</td>
<td>Sand, sandy clay, pH&gt;6</td>
</tr>
<tr>
<td>Lilium candidum</td>
<td>Sun-half shade</td>
<td>All soils, moist</td>
</tr>
<tr>
<td>Muscari spp.</td>
<td>Sun-half shade</td>
<td>Sand, sandy clay, pH +/- 7</td>
</tr>
<tr>
<td>Narcissus spp.</td>
<td>Sun-half shade</td>
<td>All soils, moist</td>
</tr>
<tr>
<td>Ornithogalum umbellatum</td>
<td>Sun-half shade</td>
<td>All soils, moist</td>
</tr>
<tr>
<td>Puschkinia scilloides</td>
<td>Everywhere</td>
<td>Sand, sandy clay, clay</td>
</tr>
<tr>
<td>Scilla spp.</td>
<td>Everywhere</td>
<td>All soils, well drained</td>
</tr>
<tr>
<td>Zantedeschia spp. (not winter hardy)</td>
<td>Everywhere</td>
<td>All soils</td>
</tr>
<tr>
<td>Convallaria majalis</td>
<td>Shade</td>
<td>All soils</td>
</tr>
<tr>
<td>Galanthus spp.</td>
<td>Light in spring, shade after flowering (deciduous trees)</td>
<td>All soils</td>
</tr>
<tr>
<td>Hyacinthina bletilla striata</td>
<td>Shade</td>
<td>All soils</td>
</tr>
<tr>
<td>Hyacinthoides non-scripta (blue bell), H. hispanica</td>
<td>Half shade</td>
<td>All soils</td>
</tr>
</tbody>
</table>


**Rosa spp. (Roses)**

Roses in their natural state grow on the forest edge and can thus be expected to grow well in partial shade. Many rose varieties are grown nowadays, mostly in full light. Probably most modern varieties will not be very productive when grown in partial shade and one should look for varieties that can still adapt to shady conditions for application in agroforestry systems.

Apart from their ornamental value, roses have exceptional nutritional and medicinal value. The hips are one of the richest sources of vitamin C, beneficial for female ailments and can be made into juice, jams, syrup and tea. Some varieties produce hips that can be eaten raw. Wild and traditional varieties are more medically potent and often more fragrant than the modern ornamental varieties (Hart 1996).

The Japanese *Rosa rugosa* produces large round hips, which are edible. It grows good in all soils if well drained, even in heavy clay soils. It fits very well in the coastal areas, since it is resistant to the sand and salt from the wind. It is a healthy shrub, resistant to most typical rose diseases. It can be grown in hedges and grows up to 1.5 m high and 1 m wide, both in semi-shade and full sun (Neerlandstuin 2004, PFAF 2004).
Other ornamental plants
Many other plants, which are locally marketed as pot or garden plants, may have potential for
cultivation in agroforestry systems as they benefit from the shade or the microclimate.
Hundreds of species of hardy ferns for instance originate from moist and shady wooded
environments and as such are excellent intercrops for established forests and older
agroforestry systems when shade no longer permits other crops to grow. Other examples are
various mosses, ornamental grasses and an endless range of shade-tolerant hardy plants,
e.g. Rhododendron, Aconitum spp., Ajuga spp., Bergenia spp., Buxus spp., Campanula
spp., Clematis spp., Digitalis spp., Epimedium spp., Euphorbia spp., Geranium spp., Hosta
Viola spp. and many others. Many of these have medicinal or edible properties as well and
may thus serve various purposes and markets. Some may be partially harvested for their
greenery, others may be cultivated in (dug in) pots and sold as such.

Merwin (2004) mentions the cultivation of nursery stock in agroforestry systems using the pot
in pot (PNP) method. Extensive information on shade-tolerant ornamental plants can be
found in various internet-sources, e.g. La Fougeraie (2004), in-de-tuin (2004), PFAF (2004),

5.4.3 Medicinal plants, herbs and aromatics
A wide range of forest plants are marketed as medicinals or as dietary supplements. They
are used in the manufacture of medicinal compounds, teas, oils, powders, food and
flavorings. Therapeutic qualities may be found in any plant organ, but mostly in roots.
Medicinal and dietary supplements form the largest segment of the non-timber forest
products (NTFP) industry. Chamberlain and Hammett (1998) mention that the estimated
global market for herbal medicines in 1996 was estimated at a value of 14 billion U.S. dollars,
half of which was represented by Europe. Markets for medicinal plants that are collected
from the forest are growing rapidly and some species are subject to overharvesting (Hill and
Buck 2000, Chamberlain and Hammett 1998. It has been proposed to set aside areas of
forest which can be farmed intensively for production of desirable forest-dependent species
(Cech 1998). Such initiatives are already taken on a large scale in North-America, in the form
of forest farming in hardwood forests. Although no such examples are found in the
Netherlands, the cultivation of valuable botanicals, either in existing forests or in specifically
designed agroforestry systems, may have great potential.

The British Agroforestry Research Trust (ART 2004) gives a selection of medicinal plants,
shrubs and trees which can be grown under the protection of a forest canopy in temperate
zones. For these species 5-40 % crown cover should be a desirable crown cover (Table 5.2).
This is a selection of only some of the species which are of medical interest and fit in an
agroforestry environment. Many essential oil crops can also be cultivated in semi-shaded
conditions, e.g. mints, lemon balm, thyme.

Both Hill and Buck (2000) and Chamberlain and Hammett (1998) give a list of medicinal
plants that are traded as medicines and dietary supplements and inhabit American forests.
Most valuable and already cultivated in American forest farming systems, are ginseng
(Panax quinquefolius) and goldenseal (Hydrastis canadensis). They grow in similar habitats;
moist, rich, deep shaded deciduous woods.
Other highly valuable medicinal species, which are known to have been cultivated, are
echinacea (Echinacea purpurea), black cohosh (Cimicifuga racemosa), blue cohosh
(Caulophyllum thalictroides) and bloodroot (Sanguinaria canadensis). These are all root
species. Black cohosh is easy to grow and thrives under lightly shaded conditions in a rich,
moist forest soil. Blue cohosh and bloodroot can be grown in similar habitats to that for
ginseng and goldenseal. Blue cohosh is not subject to pests, requires a minimum of care and
is a good candidate for commercial cultivation (Hill and Buck). Echinacea grows in open woods and likes a moderately rich, well drained soils, and is drought resistant. *Ginkgo biloba* (maidenhair tree), *Hamamelis virginiana* (witch hazel), *Celastrus scandens* (bittersweet) are species whose active properties are not in their roots. They are in high demand and could be easily cultivated in intensively managed settings (Hill and Buck 2000). *Taxus baccata*, which is a source for anti-cancer drugs, may also be considered useful for agroforestry, as it grows very slowly and stands regular pruning.

**Table 5.2: List of some medical plant species with potential for AF**

<table>
<thead>
<tr>
<th>Adonis vernalis (Spring adonis)</th>
<th>Daphne genkwa</th>
<th>Podophyllum peltatum (May apple)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrimonia eupatoria (Agrimony)</td>
<td>Digenia simplex (Makuri)</td>
<td>Potentilla fragarioides</td>
</tr>
<tr>
<td>Ammi majus (Queen Anne’s lace)</td>
<td>Digitalis lanata &amp; <em>D. purpurea</em> (Foxgloves)</td>
<td>Rhododendron molle</td>
</tr>
<tr>
<td>Anabasis aphylla</td>
<td>Gaultheria procumbens (Wintergreen)</td>
<td>Salix alba (White willow)</td>
</tr>
<tr>
<td>Anisodus tanguticus</td>
<td>Ginkgo biloba</td>
<td>Sambucus spp. (Elders - flowers)</td>
</tr>
<tr>
<td>Artemisia annua (Annual wormwood)</td>
<td>Glaucium flavum (Horned poppy)</td>
<td>Sanguinaria canadensis (Bloodroot)</td>
</tr>
<tr>
<td>Artemisia maritima (Sea wormwood)</td>
<td>Glycyrrhiza glabra (Liquorice)</td>
<td>Silybum marianum (Milk thistle)</td>
</tr>
<tr>
<td>Atropa belladonna (Belladonna)</td>
<td>Hemsleya amabilis</td>
<td>Sophora pachycarpa</td>
</tr>
<tr>
<td>Berbersis vulgaris (Barberry)</td>
<td>Hydrangea macrophylla</td>
<td>Stephania sinica</td>
</tr>
<tr>
<td>Brassica nigra (Balck mustard)</td>
<td>Hydrastis canadensis (Goldenseal)</td>
<td>Taxus brevifolia (Pacific yew)</td>
</tr>
<tr>
<td>Colchicum autumnale (Autumn crocus)</td>
<td>Hyoscyamus niger (Henbane)</td>
<td>Thymus vulgaris (Thyme)</td>
</tr>
<tr>
<td>Convallaria majalis (Lily of the valley)</td>
<td>Larrea divaricata</td>
<td>Trichosanthes kirilowii (Snake gourd)</td>
</tr>
<tr>
<td>Coptis japonica</td>
<td>Lobelia inflata</td>
<td>Urgenia maritima (Squill)</td>
</tr>
<tr>
<td>Corydalis ambigua</td>
<td>Lycoris squamigera</td>
<td>Valeriana officinalis (Valerian)</td>
</tr>
<tr>
<td>Cynara scolymus (Globe artichoke)</td>
<td>Mentha spp. (Mints)</td>
<td>Veratrum album (White hellebore)</td>
</tr>
<tr>
<td>Cytisus scoparius (Broom)</td>
<td>Panax spp. (Ginseng)</td>
<td>Vinca minor (lesser periwinkle)</td>
</tr>
</tbody>
</table>

Cech (1998) notices that ginseng is widely cultivated, while goldenseal cultivation is poorly understood and lags far behind demand in North America. He indicates that the cultivation of goldenseal is “unquestionably the most significant current herbal agricultural opportunity”. He also expects increasing opportunities for the commercial cultivation of black cohosh. Hill and Buck (2000), indicate that the cultivation of goldenseal is easier and has several advantages over ginseng, as it can be harvested in three years (compared to five or more), is easier to propagate and not subject to the disease and pest problems often related to ginseng cultivation.

Since much of the wild-crafted and cultivated botanicals in North America are meant for the export market to Europe and especially Eastern Asia, it is probable that marketing of these species in temperate Europe will not be a problem. Further research is needed to test if these species can be cultivated outside their natural habitat, since successful cultivation of any forest-dependent species will require specific conditions of shade, soil and season.

Cultivation of forest species in circumstances close to its native ecology is more likely to succeed than attempts to cultivate species in artificial environments or outside their native range. Consequently the cultivation of medicinal species from temperate Europe should be a good choice. Although little information is found on the commercial cultivation of valuable medicinal species in forest environments in temperate Europe, it is probable that opportunities for the cultivation of such species in agroforestry systems exists. Various medicinal species, such as *Digitalis purpurea*, *Convallaria majalis*, *Valeriana officinalis* and *Atropa belladonna* are found in Dutch forests, are cultivated and marketed for their medicinal properties and hence could have great potential for cultivation in the semi-natural environment of agroforestry systems. Market demands and prices paid for these plants may
however be lower than those of popular herbals as ginseng, goldenseal, black cohosh and *Ginkgo biloba*.

Ginseng is one of the most valued herbal medicines and much information is available on its cultivation. The following therefore explores its requirements, properties and economic value, in order to determine its potential for cultivation in Dutch agroforestry systems. For more elaborate information on medicinal species, their properties and requirements, referred is to PFAF (2004), ART (2004) and Hill and Buck (2000).

*Panax* spp. (Ginseng)

Various species of ginseng exist, of which the Oriental or Asiatic ginseng and the American ginseng are most well known (*Panax ginseng* and *Panax quinquefolius* respectively). Asian ginseng has a history of herbal use going back over 5,000 years. It is one of the most highly regarded of herbal medicines in the Orient, where it has gained an almost magical reputation for being able to promote health, general body vigor and also to prolong life. At present, ginseng is widely cultivated in the U.S., Canada, and China. In natural conditions, the seed may take two or three years to germinate and another three to four years to produce seed. At this age the ginseng roots can be harvested (Sadler 1999).

The North American species of ginseng is said to have similar properties to the Asian ginseng, though it is said to have a milder action. The root is harvested in the autumn and dried for later use. It is found in rich woods from Quebec to Minnesota and South Dakota to Georgia and occurs in Louisiana and Oklahoma. It grows in full shade underneath deciduous hardwood species, typically in calcium rich forest soils well supplied with organic matter (Anderson 2003). Davis (1997) recommends 75-85% shade and planting should thus be done in an established forest or agroforestry system, where canopies are well developed. Deeply rooted deciduous trees, such as walnut, poplar, oak and basswood are best for shading ginseng. Shallow rooted trees should be avoided because they offer serious competition for soil moisture and nutrients and ginseng establishment will be difficult and growth very slow. Cornell cooperative extension (2001) reports that Ginseng grows well in mixed hardwood forests, with a predominance of sugar maples. Sugar maple leaves retain their calcium when they die and fall off the tree, enriching the soil below. They also pull water up with their tap roots, which the ginseng can use. Ginseng grows well on deep moist, but well-drained soils, since wet conditions often result in rotting of the Ginseng roots. Ideally are loamy and humus rich soils, but in fact the plant tolerates a wide variety of soils, except heavy clay or light sand.

Apart from wild ginseng, which is a protected species, three types of ginseng are considered for medical use (Beyfuss 1999):
- Field cultivated ginseng is grown in raised beds in fields under artificial shade provided by either wood lathe or polypropylene shade cloth for a period of three to four years.
- Woods cultivated ginseng is grown in a forested environment in tilled beds under natural shade for a period of six to nine years.
- Wild simulated ginseng is grown in untilled soil in forests for a period of nine to twelve years or even longer. The dried roots of wild simulated ginseng closely approximate the appearance of truly wild ginseng.

Both the seeds and the roots are valuable. Under artificial shade yields of 75-100 kg of seeds in the third and 250 kg in the forth year are possible. Roots in these well managed circumstances can yield up to 1,500 kg (air dried weight) per acre. Naturally shaded plantings of comparable cultural intensity are not likely to yield more than two third as much (Davis 1997). With good growth, roots may be harvested after 4 years in artificially shaded gardens. In naturally shaded plantings harvesting may need to be delayed until the eight year or later.
There is little reliable information on the economics of ginseng. There is a great range in cultural practices with various intensities. Moreover, the economic analysis methods differ. Davis (1997) gives two estimates, based on various sources (table 5.3). The first refers to one acre of ginseng grown in the woods and harvested after 6 years of growth. The second refers to ginseng intensely cultivated under polypropylene shade. Beyfuss (1999) made similar estimations for wild-simulated ginseng and woods-cultivated ginseng (table 5.4). Persons (1998) gives similar figures as Beyfuss (1999), with slightly lower profits.

If we reverse the figures in table 5.3 and 5.4 in euro/ha (1 acre = 0.4 ha, 1 $ = € 0.83 at 22/6/04), than the net income for woodlands cultivated ginseng after 6 years would be € 74.700/ha for Davis and € 24.174/ha for Beyfuss. The contrasting figures of Davis and Beyfuss for woods cultivated ginseng are partly due to different prices for labour and harvested roots. Moreover, Davis also takes into account the income of harvested seeds, while Beyfuss does not. Field cultivated ginseng under artificial shade would yield a net income of € 157.700/ha after 4 years and wild-simulated € 67.687/ha after 9 years.

Cornell cooperative extension (2001) mentions that wild simulated ginseng in 1999 was sold for $250/pound dry. Woods grown brought about $150/pound dry and field cultivated ginseng valued at under $20/pound dry in 1999. Ginseng is currently valued based on appearance; if it looks wild it has a higher value. The roots are shaped differently in prepared beds than in undisturbed soil.

Table 5.3: Estimations on the economics of woods cultivated ginseng and of field cultivated ginseng (Source: Davis 1997)

<table>
<thead>
<tr>
<th>Costs</th>
<th>Woods cultivated, 6 years (in $)</th>
<th>Field cultivated, 4 years (in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds ($65 per pound)</td>
<td>3.900 (30 pounds)</td>
<td>6.500 (100 pounds)</td>
</tr>
<tr>
<td>Labor</td>
<td>26.600 (3.800 h at $7)</td>
<td>13.500</td>
</tr>
<tr>
<td>Shade structures</td>
<td>-</td>
<td>14.000</td>
</tr>
<tr>
<td>Equipment and supplies</td>
<td>5.000</td>
<td>4.500</td>
</tr>
<tr>
<td>Drying and packaging</td>
<td>1.500</td>
<td>14.500</td>
</tr>
<tr>
<td>Total cost</td>
<td>37.000</td>
<td>53.000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Woods cultivated, 6 years (in $)</th>
<th>Field cultivated, 4 years (in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds ($65 per pound)</td>
<td>13.000 (200 pounds)</td>
<td>39.000 (600 pounds)</td>
</tr>
<tr>
<td>Roots</td>
<td>60.000 (1.000 pounds at $60 per pound)</td>
<td>90.000 (3.000 pounds at $30 per pound)</td>
</tr>
<tr>
<td>Total benefits</td>
<td>73.000</td>
<td>129.000</td>
</tr>
</tbody>
</table>

Net income 36.000 76.000

Table 5.4: Estimations on the economics of woods cultivated ginseng and of wild simulated ginseng (Source: Beyfuss 1999)

<table>
<thead>
<tr>
<th>Costs</th>
<th>Woods cultivated, 6 years (in $)</th>
<th>Wild simulated, 9 years (in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds ($75 per pound)</td>
<td>3.600 (48 pounds)</td>
<td>1.500 (20 pounds)</td>
</tr>
<tr>
<td>Labor</td>
<td>38.000 (3.800 h at $10)</td>
<td>12.500 (650 h at $10)</td>
</tr>
<tr>
<td>Equipment and materials</td>
<td>4.650</td>
<td>500</td>
</tr>
<tr>
<td>Drying</td>
<td>1.100</td>
<td>880</td>
</tr>
<tr>
<td>Total cost</td>
<td>48.350</td>
<td>15.380</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Benefits</th>
<th>Woods cultivated, 6 years (in $)</th>
<th>Wild simulated, 9 years (in $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seeds</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Roots</td>
<td>60.000 (600 pounds at $100 per pound)</td>
<td>90.000 (80 pounds at $300 per pound)</td>
</tr>
<tr>
<td>Total benefits</td>
<td>60.000</td>
<td>48.000</td>
</tr>
</tbody>
</table>

Net income 11.650 32.620
Considering the relatively high and long term investments and the unpredictable yields and prices, ginseng appears to be a risky crop. On the other hand it can be very profitable. Regarding the prudent calculations of Beyfuss, woodland-cultivated ginseng would still give a net annual profit of more than € 4000 per ha, which is very high compared to the average net annual profit of € 1000-2000 per hectare of food crops in the Netherlands. It is therefore, recommended to start on a small scale and expand if preliminary results and prices appear to be good.

If the roots of ginseng grown under agroforestry have the appearance of woods cultivated ginseng, the cultivation of ginseng in Dutch agroforestry systems seems to have high potential. However, if agroforestry grown ginseng gets the same price as field cultivated ginseng, ginseng may not be a profitable intercrop. Although the figures of Davis in table 5.3 may predict otherwise, Beyfuss (1999) remarks that in recent years the world market price for field cultivated ginseng has dropped to near the actual cost of production ($ 12-20/pound). The prices of woods cultivated and wild simulated ginseng, on the other hand, have risen to levels that, according to Beyfuss (1999), can be extremely profitable for landowners with suitable forest stands. agroforestry experiments will have to proof if ginseng cultivated under agroforestry will fall under the category of woods cultivated ginseng.

At present, most ginseng is sold to Eastern Asia, but American ginseng is gaining popularity among American and European consumers. Eventually a market for "organic" ginseng can be expected to develop, as western people become more familiar with this product. Woodland cultivation is the only possible way to grow ginseng "organically". Currently, the production of woodland ginseng is so limited that almost all of it is exported to Asian countries.

**5.4.4 Specialty vegetables**

There are thousands of plants with edible leaves, but the modern world has only focused on very few species, most of which are annuals, such as lettuce, cabbages, and common spinach. Adding less known vegetables to the agricultural landscape, especially perennial vegetables, could contribute to the diversity of the agroecosystem and people’s diet. Many of these species are tolerant to partial or even full shade and as such have high potential for integration in the later phase of agroforestry systems, when light demanding crops are no longer able to grow. Although they may be easily grown and very productive, many of these vegetables cannot be harvested with machinery as used for common annual vegetables. Hence they are usually more labour intensive. Related to this, markets for many of these plants are not yet developed. This makes them most useful for small-scale and innovative farmers and especially suitable for home consumption.

It is impossible to describe all possible vegetables, so chosen is to make a selection of vegetables, which have proven their value (i.e. good growth, yield and taste) in the permaculture and forest gardening movement and which are especially suitable to combine with trees for their shade-tolerance. More extensive information can be found in the database of edible plants of the Plants For A Future (PFAF 2004).

*Brassica juncea* (Mustard)

This is a very hardy vegetable from the Orient, where it is highly appreciated for its flavor. Various varieties grow well in our climate. It grows on most soils, if moist and well drained and preferably fertile. It grows well in sun and half-shade. The leaves can be cooked or eaten raw and can also be harvested in winter. The seed is used a mustard flavoring and various varieties exist of which also the root and stem can be eaten (PFAF 2004).
Cryptotaenia japonica (Japanese parsley, mitsuba)
This short-lived perennial grows to 1 metre tall when in flower and about 60cm wide. It
succeeds in most soils, preferring a moist shady position under trees where it often self-
sows. It may not be winter-hardy in all areas of the Netherlands. It is usually grown as an
annual, though plants can tolerate short periods at temperatures down to about -10°C.
Mitsuba is commonly cultivated as a vegetable in Japan (PFAF 2004). The leaves and stems
can be eaten raw or cooked (shortly) and have a parsley-like flavour. The seedlings and
young leaves can be used in salads whilst older leaves are used as a flavouring.

Claytonia perfoliata and C. sibirica (Miner’s lettuce and pink purslane)
These species are particularly suitable to grow in shade, even in dense shade, although they
grow in sunlight as well. C. siberica is a short lived perennial and C. perfoliata is an annual,
but since they self sow freely, they can be used as a dense perennial ground cover,
providing edible leaves year-round. They are very hardy and will grow on most soils, even
nutrient poor soils, but C. sibirica requires moist humus rich soils for best results (Fern 2000,
PFAF 2004).
Both are easy and very productive salad plants of which both leaves and flowers are edible,
raw or cooked.

Allium ursinum (Wild garlic, daslook)
This is a native protected species that can grow prolifically in woodlands, often forming large
colonies. It prefers a moist well-drained and calcium rich soil and is often found in the wild
growing in quite wet situations. Plants come into growth in January or February, they flower
in the spring and have completely disappeared by mid summer, thus allowing other plants to
grow in the same space during the summer.
The leaves, coming as they do in late winter, are a very welcome addition to our salads and
cooked foods. They have a moderately strong garlic flavour, though this reduces as the
leaves get older. The flowers have a slightly stronger flavour and make a very attractive
addition to salads whilst the small bulbs can be used just like garlic (Fern 2000, PFAF 2004).
Since they are very attractive they can also be marketed as an ornamental garden plant.

Asarum canadense (Snakeroot, mansoor)
This plant grows about 10cm tall but spreads slowly to form clumps 50 cm or more across,
making a good ground cover. It prefers a rich moist neutral to acid soil though it is also found
on alkaline soils in the wild.
The underground stem and the flowers are used as a ginger substitute. The root has a
pungent, aromatic smell like mild pepper and ginger mixed, but more strongly aromatic. It is
best harvested in autumn but is available all year round and can be dried for later use (Fern

5.4.5 Gourmet mushrooms
Gourmet mushrooms are commonly grown in American forest farming systems (Hill and
Buck). Best known and of most interest for (agro)forest owners is the shiitake mushroom
(Lentinula edodes), which is cultivated on small 10-20 cm diameter hardwood stems (e.g.
beech, maple and, preferably, oak logs), which may be the products of thinnings (Hill and
Buck 2000). Using this roundwood for the production of gourmet mushrooms may be
especially cost-effective for owners of small woodlots or agroforests, with unmarketable
amounts of thinnings. It should be considered that the harvesting of mushrooms is rather
time consuming and that the market demand for these expensive mushrooms is thin.

Inoculated logs take 6 to 12 months to produce the first mushrooms, depending on the strain
of spawn used, species and size of logs and the macro- and microclimate. Logs can produce
for 5 years and may be soaked repeatedly to force fruiting. Logs are estimated to produce at
least 100 g of shiitake per kg of wood during a five year production cycle (Hill and Buck 2000).

In addition to shiitake, oyster (Pleurotus sp.) maitake (Grifula frondosa), reishi (Ganoderma lucidum) and linon’s mane (Hericium erinaceus) depend on the digestion of wood fiber and may be considered for cultivation in agroforestry systems (Hill and Buck 2000). These can all be produced in a similar manner. Another option may be to cultivate shiitake or oyster mushrooms on tree stumps. In France and Hungary poplar stumps are cleaned up in this way, saving the money of mechanical removal (Oosterbaan and Valk 2000).

5.4.6 Apiculture

Agroforestry systems are very suitable for apiculture, the care and management of honeybees for various products and/or for pollinating agronomic or tree crops. Hives can be introduced in existing forest systems (i.e. forest farming), or new plantings could be designed to favor bee forage (Hill and Buck 2000, Hill 1998). Fruit trees require bee pollination for effective fruit set. Other trees, as black locust (Robinia pseudoacacia), chestnut (Castanea sativa) and Tilia spp. are known to have flowers that produce nectar and pollen attractive to bees and can produce high quality honey (Hill and Buck 2000).

If managing a forested area in part for bee forage is desirable, it may be important to thin the existing trees enough to expose more of the trees’ crowns to sunlight as exposed tree crowns provide a greater surface area in relation to the volume of the crown to produce flowering bee forage (Hill and Buck 2000). This again may give opportunities to grow other products under the tree crowns. In silvopastoral and silvoarable agroforestry, planting bee forage in the tree line may favor honey production and provide additional income. Apart from honey, apiculture can produce valuable products as beeswax, propolis, royal jelly, bee venom (for therapeutic uses) and bee pollen.

5.5 Crops for fiber and bio-energy production

During the last decades, the Dutch government has been stimulating farmers to take arable land out of production to decrease overproduction. One example of this is the planting grant for fast growing trees (poplar) on arable land. This planting grant however, is not given for intercropped poplar, because this would still mean a contribution to the overproduction (Edelenbosch 1994). Nevertheless, agroforestry could contribute to the decrease of overproduction, especially when choosing non-food intercrops, as the production of bio-energy or fibers.

Moreover, production of fibers and of biomass for bio-energy have been proposed as promising alternatives for the production of conventional agricultural products, of which revenues are ever-decreasing. The market for fibers and bio-energy is supposed to rise in the near future, making the production of crops which yield such commodities interesting for farmers.

A variety of crops for fiber and bio-energy have been investigated in recent years. In this report, the stress is put on two very promising crops, namely hemp for fiber-production and short-rotation coppice for bio-energy. Both have interesting qualities as intercrops in agroforestry systems.

5.5.1 Hemp

Hemp (Cannabis sp.) could probably be a very good intercrop for the first years of tree establishment. Various researchers (Edelenbosch 1994, Garrett and McGraw 2000), suggest hemp as an excellent intercrop species, among others for its good market-perspective. Hemp
grows well under the Dutch climatic conditions and thrives on all soils except very poor sands such as the Veluwe. Hemp would grow best on fertile soils, such as the northern and southwestern sea clay areas and in the “Hollandsepolders” and “Ysselmeer-polders”. De “Veenkolonien” are moderately suitable for the cultivation of hemp (van Soesbergen en van Lanen 1992).

At present, narrow cropping plans, overproduction and decreasing prices of conventional agricultural products are major problems in Dutch agriculture. Hemp could add to the cropping cycle (and thereby decrease the problems with soil bound pests and diseases) and decrease the production of conventional crops and the use of agrochemicals. Hemp has the habit to quickly cover the soil surface and outcompete weeds. Furthermore, most literature reports that hemp suffers from few pests and diseases. Van der Werf et al. (1994), however, found that in wet years hemp can suffer severe damage from fungi in the Netherlands, especially of Botrytis cinera. Fungicide applications did not increase stem yield. Therefore, there is no reason to use pesticides in hemp: herbicides are superfluous, fungicides have not found to be effective and other biocides are not needed. The plant requires relatively little fertilizer in comparison to other fiber crops and additionally it has the ability to clean contaminated soil (Robinson 1996). Kok et al. (1993) investigated the effect of fiber hemp on three major soil pathogens: the fungus Verticilium dahliae and the root-knot nematodes Meloidogyne chitwoodi and Meloidogyne hapla. All three pathogens were suppressed by hemp, indicating that the introduction of hemp in a crop rotation might improve soil health.

Van der Zwan (1982) suggests that hemp could be a good addition to the usual rotation of potatoes and sugarbeets/cereals in the Veenkolonien. Intensive cultivation of starch potatoes in this area has led to declining soil quality (low organic matter and sensitivity to wind erosion) and an increased disease pressure. This has resulted in decreasing yields and increasing costs of spraying, making it harder and harder for farmers to survive. According to van der Zwan, hemp would probably be an economically viable alternative crop. If sown in high densities, self-thinning of hemp automatically means that organic matter is added to the soil. This, combined with its abilities to control the growth of weeds, and probably also that of wild shoots of potatoes and sugarbeets, makes hemp especially interesting for the Veenkoloniën.

Also van der Werf (1994) concludes that fiber hemp has a high potential as a “new” crop in Dutch agriculture: “growing hemp may be economically worthwhile for Dutch farmers, hemp stems potentially have a large non food market, and the crop requires little or no biocide and suppresses weeds and some major soil-borne diseases”.

Hemp is usually sown at high densities, leading to intra-specific light competition and thus increasing length growth and self thinning from canopy closure. This stem elongation is a so called shade-avoidance strategy (Terhurne 2001). Increased length growth is preferable, because it leads to more of the valuable product, the fibers. Possibly hemp would show the shade-avoidance strategy in a similar way in agroforestry, which would mean that less seeds per hectare are needed to attain stem elongation. Since hemp grows quite high (up to about 3 - 5 m), inter-specific light competition between the hemp and young trees would force both crops into length growth. As in high-density plantation forests, the trees would form straighter and longer logs with less intensive pruning. Nair (1993) describes a similar old Chinese agroforestry system, whereby seedlings of Sophora japonica was grown together with Hibiscus sp. to obtain vertical and uniform tree seedlings for planting along roadsides. A disadvantage of high crops is the decreased ventilation of the tree canopy, which may increase the impact of diseases on its foliage (Dupraz and Newman 1997).

Almost every part of the hemp plant can be used by industry: the grain like seed, the strong fiber and the woody core. Hemp fibers are used for many things, amongst others for the production of textiles and paper (for extensive information, see Brown 1998, Robinson 1996).
Since hemp has the ability to produce up to 4 times more fiber per hectare than trees do, it a perfect alternative for the production of paper pulp (Robinson 1996, van der Zwan 1982). The stalks and seeds can be used as an energy source. Since hemp is harvested yearly, it may be a more interesting option for farmers to grow hemp than to invest in long term poplar plantations for pulp production. Experiment of Terhurne (2001) in Italy even showed that the best quality hemp can be harvested at 400°C days, giving this “baby hemp” a different place in the cropping system, which makes it more attractive. It can then be grown as a second crop after an early crop such as seed potato, or two consecutive hemp crops can be grown.

Despite the many advantages of hemp, it is only recently that various western countries rediscovered the values of hemp and starting to cultivate again after decades of legal suppression. It is still a rather unfamiliar crop and most hemp markets are still in their infancy. According to Robinson (1996) industrial countries will need to invest in the design of new farm machinery before large scale plantings will be cost-efficient. Bakker and Van Kemenade (1993) though, conclude that fiber hemp for pulp is potentially a profitable crop for arable farmers in the Netherlands, if a pulp factory is set up. Also de Meijer (1993) noted that the main factors for a successful introduction of hemp as a pulp source are not botanical or agricultural, but industrial and political considerations. However, more than twenty companies in Europe alone are engaged in the primary processing of hemp, of which several in the Netherlands. Demands in 2001 were higher than the supply, due to the increasing establishment of hemp as an industrial fiber and the simultaneously decreasing EU subsidies. Karus (2002) mentions that in 2002 the seven main companies intended to considerably increase their combined contract area to more than 14,000 ha (+40 %). He remarks that, it is questionable whether enough farmers can be found to grow hemp under the current (and future) economic conditions.

In Canada, enzyme technology processes are being developed that reportedly may have hemp fibers replace cotton worldwide (Hemptown 2004). Such developments could make the cultivation of hemp even more attractive.

5.5.2 Short-rotation coppice for bio-energy

All over the world researchers are looking for sustainable alternatives for fossil fuels. Apart from the growing concerns about the exhaustion of these finite resources, more recently the concerns about human-induced climatic changes have led to numerous investigations on sustainable solutions. One of the alternatives receiving much attention, is that of bio-energy crops. The European union and the Dutch government have pledged enormous support to turn the current vision of sustainable energy production into reality. The Dutch government has proposed a target share of 10% of the national energy demand to be fulfilled by renewable resources by the year 2020 (and 5 % in 2010). Twenty-five per cent of this renewable energy must be produced using biomass (Brinkhorst 2000). This is more than seven times the yearly yield of wood-thinnings in the Netherlands (Kuiper en Jansen 2002).

Sweden and Britain lead the science and technology for biomass production in temperate climates. In the last 20 years enormous research and development have been done in this area, particularly that relating to willow and poplar trees grown as arable crops using agroforestry techniques and more popularly known as short-rotation coppicing (SRC). Straw, peat, forest residues and energy coppice are already providing some 15 percent of Sweden’s total energy requirements. Also in the UK and the USA there are numerous examples of heat and electricity production from wood, often by independently owned biomass power plants (Macphersons 1995).

Short rotation coppice reportedly gives farmers the opportunity to use government and EU assisatance in a constructive and productive way rather than simply leaving land under unsightly set-aside (Macphersons 1995, SBH 1994). However, long-term contracts are
suggested to guarantee farmers of a market for SRC (SBH 1994). Farmers could sell their products to produce heat or electricity, or both. Potential non-energy markets for SRC may be chipboard factories, the pulp- and paper industry and the charcoal market (Macphersons 1995). Another option may be to produce heat and/or energy on a small scale for on farm use, e.g. for horticulural uses or heating and lighting the homestead (Macphersons 1995, SBH 1994). Tholhuijsen (1986) calculated that half a hectare of poplar can yield enough firewood to replace 3000 m³ of gas. On this small scale, with little mechanisation and home-use of the energy, the system would give a revenue equalling that of maize.

According to Macpherson (1995), the advantage of SRC above other alternative arable crops, which often require the finding or creation of niche markets, is that the potential market is healthy and growing. SRC, for now, offers everything that the farmer could want; low labour, high production, low fertilizer or chemical requirements, large acreage, use of existing machinery (standard arable implements for seedbed preparation and almost standard forage harvesting gear for coppice harvesting), environmental enhancement and a high potential for public acceptance. The main question is if the farmer could sell it for a good price, i.e. is it profitable?

In the Netherlands, currently only residues are traded for bioenergy on a commercial basis to feed several power plants in the Netherlands. Prices for forestry residues, (clean) waste wood and other biomass types of comparable quality, vary between € 0 and € 25 per oven-dry ton (odt) before transport, which are assumed to be competitive with fossil fuels such as coal (Londo 2002). Londo (2002) calculated that willow biomass production in single-land use energy cropping on agricultural land can never compete with this price. The low value of biomass means that dedicated energy crops can not compete with common agricultural crops and the introduction of energy farming as single land use will hardly have a chance. Furthermore, on the long term the availability of land in the Netherlands is too limited to cover the expected future need for the production of energy crops.

Multiple land use is suggested as a solution to improve the financial competitiveness of energy crops and to tackle the problem of future land scarcity (Londo 2002, Windt et al. 2001). As an option to reduce break-even prices and hence make prices of willow coppice competitive with those of residues, Londo (2002) proposes to avoid competition for land with common agriculture, but to seek for land dedicated to e.g. nature conservation and recreation. An additional advantage in this respect is the possibility to grow willow without or with low fertilizer and biocide application, making it attractive in groundwater protection areas, groundwater extraction areas and as a habitat for a range of animals, e.g. breeding birds. Through some of these applications indeed a significant competitiveness increase can be obtained. However, Londo (2002) predicts that the price reductions are not in the order of magnitude that the price of energy crops draws near to the current prices of biomass residues.

Although, according to Londo (2002) perspectives for willow short rotation coppice may be limited on the short term, this could well change in the future by technical innovations in energy cropping, leading to more competitive supply prices through decreased cultivation costs and increased productivity. Furthermore future changes in the current market regulations and supportive payments to farmers may make energy crops more competitive. For instance the introduction of multiple land use energy farming on fallow land under the EU set-aside scheme could be an option. More governmental incentives to the development of energy crops, as in Sweden and the UK (Macphersons 1995), could be another option. Finally, if climate change concerns lead to increasing demands for bioenergy, or to a pricing system of CO2 emissions, energy cropping may benefit, especially when the amounts of available residues are not sufficient to meet demands. Hence the development of SRC for biomass production are greatly dependent on decisions at the international level. Windt et al.
(2001) however, conclude that the reasons that the large-scale cultivation of biomass is not running so fast, are for the major part a lack of awareness or a lack of clarity and the difficulty to get the various actors together and on one line.

Within the concept of multiple land use, also the cultivation of short rotation coppice as intercrops (i.e. intertrees) in the alleys between standards of valuable tree species for log production can be an option. Such management systems will thus include only trees and consequently are not agroforestry systems in the strict sense (see Paragraph 1.4). They are essentially similar to two-strata forest ecosystems. Dupraz and Newman (1997) mention that new agroforestry systems are now designed with alleys of coppice between lines of hardwood trees. On wet land willow SRC may well combine with red or black elder standards for veneer production. On drier grounds standards of poplar, ash, maple, wild cherry or walnut for log production may be an option. Since no such examples are reported in the Netherlands, such combinations may require further exploration to determine their viability.

5.6 Conclusions

Until now, agroforestry research in temperate Europe has mainly focused on the integration of conventional, intercrops and trees. Although in principle any crop can be grown, most promising seem to be rowcrops as maize and cereals, grass, leafy vegetables and particularly wintercrops. The conventional crops are rather light demanding, and in agroforestry their production may be highly reduced due to sub-optimal light conditions under large trees. At this point often replacement of the light demanding crop by shade-tolerant forages (grass, clover), reducing the intercrop width or leaving the alleys bare are the recommended alternatives. It is questionable, however, if these are the most sustainable options, both in terms of economy as ecology. There is a broad range of interesting alternatives, which can produce valuable products in the (shaded) alleys, both on a large scale for the bulk market and on a smaller scale for certain niche markets.

Some innovative alternatives, like free range poultry, small fruits, short rotation coppice and certain ornamental and medicinal plants have a great potential for large scale production on intensive mechanized farms. Others, such as production of “wild” meat, specialty vegetables, gourmet mushrooms, certain small fruits and herbs and fragile ornamentals may be of interest for more extensive land users and can yield a variety of valuable products for various niche-markets.

Agroforesters actually have the choice of a multitude of intercrop options, many of which need further investigation before application. Special interest deserve the cultivation of shade-tolerant small-fruit, gourmet mushrooms and high-value medicinals as ginseng and the cultivation of non food crops for fiber and biomass production, as well as the production of free range poultry and “wild” meat in agroforestry systems. As with trees, the optimal choice of species will depend on the specific situation regarding ecological, technical and economic aspects as well as farmers objectives. The appropriate tree-crop combination and the system design are crucial in terms of reducing competition and hence optimizing the land equivalent ratio (LER). The interdependence of the various factors and suggestion for Dutch agroforestry practices are elaborated in Chapter 8.
6. Governmental regulations and subsidies with (possible) relevance to agroforestry

Although subsidies and regulations are subject to regular changes, the following gives some insight in the current regulations and grants, which may be of use and of importance for agroforestry. For up to date information it is useful to check the website of the ministry of LNV (LNV-loket 2004).

6.1 Restrictive regulations

Through the re-allotment and the increasing efficiency of Dutch agriculture, many farm-forests and solitary trees have disappeared from the rural landscape. To prevent a further erosion of trees from the Dutch countryside and to increase the production of wood in the Netherlands, the Dutch government implemented a regulation to oblige landowners to announce the felling of trees on their land and to replant trees after felling (regeling meldings-en herplantplicht). This implies that an arable plot with trees may obtain the status of forest, which means that the plot will fall under the forest law and considerably decrease in value.

This regulation is very important to consider when planting trees. For temporary tree plantings however, it is possible to ask ‘exemption of the replant-obligation’ (ontheffing van de herplantplicht), which was introduced to promote the establishment of plantations of fast-growing trees on farms. The exemption however, is currently only permitted if the trees are felled within 40 years. If these regulations are maintained in the future, this means that landowners who do not ask for ‘redemption’ or maintain their trees for a longer stretch of time, have a chance to be obliged to plant new trees after felling and see their land shifting to a forest status (i.e. decrease in value).

Besides these regulations, which fall under the Dutch forest law, one should also take into account regulations on the municipal and regional level, when considering the establishment and felling of trees.

6.2 Grants on tree planting and/or maintenance

In the Netherlands various subsidies are available to maintain elements of ecological or cultural value. These subsidies fall under the ‘subsidy agrarian nature-management’ (subsidie agrarisch natuurbeheer, SAN). Several of these are directly aiming at specific forms of AF, others may have relevance for alternative agroforestry systems. Usually the subsidies are given if the management-unit is maintained according to the rules for 6 years, after which the contract may be extended with another 6 years and so on. Sometimes also establishment subsidies are available. In this paragraph the conditions of these arrangements and the current height of the subsidies are described.

It must be noted however, that it always depends on the province if subsidies are provided:

- the element should fit within the conditions of the provincial area-plan, which decides which kinds of nature should be developed and maintained in which area. The only exception to this rule is fast growing forest, which does not have to fall within the boundaries of the area-plan to receive subsidies
- every province has hectare-quota on their subsidies. If the quota for a package is full, no more subsidies can be given on that package
This chapter is only aiming at giving suggestions on the interpretation of the subsidy regulations, which may favor the application of agroforestry within these subsidy-systems. Apart from the subsidy on high-stem orchards, mentioned hereafter under point 1, the other subsidized systems are aimed at short rotations or copse wood. Although the inclusion of valuable trees for a longer term seems possible considering the rules on paper, this should be reconfirmed in practice.

For more extensive and up to date information on subsidies and regulations, referred is to LNV-Loket (2004) and Steunpunt Hoogstamfruit (2004).

1. High-stem fruit/nut orchards (landscape package 60, package-code 3600)

Recently the Dutch government is stimulating the planting and maintenance of high-stem fruit trees to bring back the traditional high-stem orchard in the cultural landscape. Via the ‘subsidy agrarian nature-management’ (subsidie agrarisch natuurbeheer, SAN) or the ‘fund for renovation of the countryside’ (fonds vernieuwing landelijk gebied) it is possible to receive subsidies on the establishment or renovation of high-stem orchards of more than 15 trees.

If more than 0.25 ha is planted it is also possible to receive a yearly management subsidy of € 14,89 (2004) for each tree, if the system is according to the following conditions:

- orchards may consist of walnut-, apple-, pear-, plum or cherry trees
- the trees must measure over 4 m when mature
- densities must be over 50 and under 150 trees/ha
- management should only be aimed at maintaining the cultural element. Apple and pear must be pruned at least every two years. The orchard must be yearly mown or grazed
- no chemicals and artificial fertilizers should be used in or near (<1 m) the element

2. Fast growing (temporary) forest

a) Fast growing (temporary) deciduous forest (management package 31, package-code 3310)

Conditions:

- at least 90 % (crown-projection) of the area consists of forest
- at least 80 % of the area is occupied with the following species:
  - eur-american poplar
  - schietwilg
  - west-amerikaanse balsempopulier
  - zwarte balsempopulier
  - zwarte populier
  - a minimum of 400 trees/ha
  - a minimum area of 5 ha

b) Fast growing (temporary) pine forest (management package 32, package-code 3320)

Conditions:

- Similar as under a), but with a minimum of 2500 trees per ha and the following species:
  - Corsicaanse den
  - Douglas
  - Fijnspar
  - Sitkaspar
  - the trees are not to be used as christmas trees
Both receive a subsidy of E545,-/ha/y (2004) in three terms of 6 years, so 18 years in total. On forehand an 'exemption of the replant-obligation' must be submitted, to prevent the plot of falling under forest law, which includes the obligation to replant forest after felling (see Section 6.1). On this package also an establishment -subsidy is available. Herefore a set-up plan must be made and approved upon.

These regulations would theoretically permit a 20 % cover with other, more valuable and long term species. It remains unclear however, if the whole plot should be harvested within a short rotation to obtain the subsidies, or if it would be possible to maintain certain trees for a longer term.

3. Tree row or hague (landscape package 65, package-code 3651)

Conditions:
- it is a linear element, covered at least 90 % (crown-projection) with indigenous shrubs and trees
- it is at least 50 m long and maximum 20 m wide
- it consists of copse wood, but may contain not coppiced trees
- management should only be aimed at maintaining the cultural element
- management measures should only take place between september 1 and april 1
- no chemicals and artificial fertilizers should be used in or near (<1 m) the element

In theory the not coppiced trees could form a valuable and long term tree component, while the copse wood could act as an intercrop, e.g. for biomass production.

This system would receive a subsidy (2004) depending on the crown-projection:
E657,61/ha/y for a cover higher than 90%
E493,21 /ha/y for a cover between 75 and 90%
E328,81/ha/y for a cover between 50 and 75 %

4. Borders of elders (elzensingel) (landscape package 54, package-code 3541)

Conditions:
- subsidies are given on the maintenance of continuous strips of native greens, which consist for 80 % of black alder
- the strips are minimally 50 m long, consist of copse wood and contain a maximum of 3 trees per 100 m, which are not coppiced (overstaanders)
- the other trees should only be 0.15 m diameter (at 1.30 m above the trunk), or 0.25 m in sandy areas
- management should only be aimed at maintaining the cultural element. This means regular pruning at 0.1-0.3 m height
- management measures should only take place between september 1 and april 1
- no chemicals and artificial fertilizers should be used in or near (<1 m) the element

This system would receive a yearly subsidy (2004) of depending on the crown-projection:
E29,89 per 100 m for a cover (crown-projection) higher than 90%
E22,42 per 100 m for a cover between 75 and 90%
E14,95 per 100 m for a cover between 50 and 75 %

Hence this arrangement would permit the inclusion and maintenance of valuable native trees for logproduction at low densities (max. 3 per 100 m length) and hence create possibilities for extensive agroforestry systems.
5. Farmer's copse wood forest (geriefhoutbosje) (landscape package 55, package-code 3550)

Conditions:
- the area should be between 0.05 and 0.5 ha and contain at least 5000 stems of indigenous trees per ha. The element should consist of copse wood, of which a maximum of 500 are not coppiced (overstaanders)
- management should only be aimed at maintaining the cultural element. This means regular coppicing at maximum 50 cm above ground or just above the trunk if it is higher
- management measures should only take place between september 1 and april 1
- no chemicals and artificial fertilizers should be used in or near (<1 m) the element

This system would receive a subsidy of E597,83,-/ha/y (2004).
This arrangement may create possibilities of small scale agroforestry with valuable indigenous trees (e.g. chestnut) and copse wood as an intercrop.
7. The reaction of Dutch farmers to new silvoarable and silvopastoral systems

Executive summary of the attached report

7.1 Introduction

At present, knowledge on agroforestry in general is quite poor in the Netherlands as in most other European countries. This is due to the marked decline in agroforestry systems across Western Europe throughout the last century. In the Netherlands, with the exception of windbreaks and riparian buffers, agroforestry plays currently no role. Re-introduction of such systems requires first of all an information exchange between potential agroforesters and institutions with interest in agroforestry. In this context, the SAFE-project developed and performed a survey in 7 European countries, i.e. France, Spain, UK, Germany, Greece, Italy and the Netherlands. This chapter provides an executive summary of the survey results in the Netherlands. The complete paper is attached to this report. The methodology and the aims were the same for each country.

7.2 Objective and methodology

The principal aim was to explore the interest of Dutch farmers and estate owners in agroforestry and to determine the conditions of acceptability of new agroforestry systems.

The survey consisted of three steps. First respondents were asked whether they knew agroforestry and what it was, followed by information on agroforestry by means of a PowerPoint presentation. Then technical questions on the design and implementation of a virtual agroforestry project were asked. Finally the respondents were asked to evaluate agroforestry, which issues they expected to constrain the adoption agroforestry and how these issues could be solved.

In January 2004, the questionnaires were held under 27 farmers and 2 estate owners in two rather different regions in the Netherlands, namely the Achterhoek and North-Friesland. Within each region farmers were randomly selected from a list, which was purchased from AgriDirect in Dronten, a specialist in Agrimarketing. Two estate owners were randomly selected from a list of estate owners in the Achterhoek, that was obtained through GPG (Landowners Organization of the province of Gelderland, of which the Achterhoek is part).

7.3 Research area

The Achterhoek is located on sandy soils in the East of the Netherlands. The region is traditionally characterized by mixed farming, relatively small farm and plot size and many woody landscape elements. Trees are abundant. The many estates contribute for a major part to the cultural-historical and natural values of the area.

Northern Friesland, is located on the clay-soils in the North of the country and is characterized by large farm and plot size (compared to those of the Achterhoek) with more
specialized and intensive land use. The landscape is traditionally very open. Plots are often separated by ditches and hardly any trees or bushes are found in or around arable fields.

7.4 Results

For both the Achterhoek and N-Friesland the concept of agroforestry as being “wide-spaced trees intercropped with arable crops” (SAFE 2004), is new. None of the respondents has seen or heard of agroforestry as such. Since most farmers have rather experienced the negative aspects of trees for the farm economy, farmers tend to be sceptical about the feasibility of agroforestry in their situation. Although farmers were interested in the concept, in general farmers saw better options for agroforestry in areas where plots are larger and agriculture and the accompanying pressure on land are less intensive, such as the marginal areas in the northeast of the Netherlands, France or Eastern Europe. For the majority of the respondents it holds that if the system brings in enough money, they are interested to apply it on their farm. But farmers see more opportunities for hobby-farmers or stopping farmers, who are not financially dependent on their agroforestry plots.

In the Achterhoek, many fields are bordered by tree lines or bushes and thus farmers are more used to trees, their effects on crops and the work for tree maintenance. That may be the reason that farmers in the Achterhoek are more open to agroforestry than farmers in the open Friesian landscape. Friesian farmers think trees do not belong in the open landscape, that they will increase pest pressures on the crops and have an adverse effect on the traveling birds.

Farmers in both regions see a lot of negative aspects of agroforestry (Figure 7.1), mostly of a technical matter: problems with mechanization, labor, shade and related to those decreased revenues on the intercrop.

![Figure 7.1, Negative aspects of agroforestry named first in both regions (t=29)](image)

Consequently, various environmental values as landscape value are considered the major positive aspects of agroforestry (Figure 7.2). Landscape value is also the major reason to maintain trees on the farm, apart from the fact that farmers are forced by law to maintain trees (Paragraph 6.1).

Most farmers emphasize the need for subsidies to compensate for the losses on the revenue of the intercrop and the expected extra costs for labour and tree maintenance. On the other
hand, many farmers underline that government subsidies and regulations are subject to change and hence a risk factor. Clear and long-term subsidies and regulations can be considered a primary prerequisite for the successful introduction of agroforestry in the Netherlands.

Another constraining factor is the lack of knowledge on the management of the trees, the returns of wood and the wood-market. Since most farmers have the experience to gain little or no money by the sale of wood, they have little confidence in the profitability of agroforestry. Clear calculations of the returns of agroforestry in the Dutch situation are necessary to convince farmers of its feasibility.

![Figure 7.2, Positive aspects of agroforestry named first in both regions (t=29)](image)

Especially farmers in the Achterhoek were open to the idea of managing the intercrop if their neighbour would start agroforestry (Figure 7.3). Farmers were a bit more reluctant in accepting the intercropping area, if their landlord would start an agroforestry project on the land they were renting. The interest of estate owners for such co-operation needs further investigation.

Friesian farmers were more conservative in cooperation with neighbors and landlords, which may be explained by the fact that they are less dependent on landlords compared to the farmers in the Achterhoek.

![Figure 7.3, Willingness to accept an intercropping area from a neighbour (n=27)](image)
Proposed was furthermore to explore the possibilities to let other parties, such as nature organizations or enterprises, take the care, risk and profits of the tree component and let the farmer manage the intercrop area. Another option to give farmers more security may be to let government or enterprises guarantee a certain wood price on stem.

Since farmers have little or no experience with tree production in general and agroforestry in particular, they find it hard to decide how they would design and manage an agroforestry system. Farmers pointed out to need much more background information and practical examples to make reasonable decisions on this. Nevertheless, most farmers predicted that they would choose large distances (20-25) between the tree rows to make for a good and healthy intercrop. Distances would be adjusted to the width of the machinery. Distances within the tree row will not affect the machinery and can thus be taken shorter to still come to a good wood production. Farmers in the Achterhoek were more willing to do the operations and the tree maintenance themselves than Friesian farmers. This may be explained by the fact that they already have to cope with trees on (the borders of) their farm and as such they often know about the tree maintenance.

Respondents found it hard to choose tree species for agroforestry. Favorite were fruit trees and poplar, as these give early benefits. Grass, cereals and maize were considered the best conventional intercrop (Figure 7.4), although most farmers doubt whether the intercrop will not suffer too much from shade and humidity (problems with drying/ripening). A grass-cover is also the most popular option for soil maintenance of the tree strip and as land use option when annual intercrops become unprofitable. Various alternative and possibly shade tolerant intercrops were proposed.

![Figure 7.4, Best intercrop according to farmers in the Achterhoek (t=14) and N-Friesland (t=15)](image)

62% of the respondents in the Achterhoek said they would like to try an agroforestry project. Only 27% of the Friesian farmers were enthusiastic to try an agroforestry project. Whether respondents would adopt agroforestry would not so much depend on respondents’ age, but rather on profitability, the subsidies and on the (availability of a) successor.

### 7.5 Conclusions

Comparing the two regions, it can be concluded that the circumstances for the development of agroforestry are better in The Achterhoek. Farmers are more positive about the concept and seem more interested to try an agroforestry project. Furthermore they already have
experience with trees and are more open to co-operation with neighbors and landlords. The
decreasing farm profits on the sandy grounds in the Achterhoek, increasing regulations and
the limits to further intensification seem to force farmers to take a broader view on
agriculture. The same may hold for other marginal areas in the Netherlands. Moreover, both
the political and biophysical climate in the Achterhoek may be better for the introduction of
agroforestry.
8. Synthesis and discussion: roadmap for adoption and design of new agroforestry systems

8.1 Introduction

The aim of this study is ‘to explore the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands’.

Research and practice in other temperate regions suggest that agroforestry may have potential as a multiple land use system in the Netherlands. However, the way farmers and other land users make decisions and plans depends on many interacting variables (factors): what they aspire (objectives), what they believe to be true about the biophysical and social world (knowledge and insight), and what they (think they) are able and allowed to do (Leeuwis and van den Ban 2004). These variables shape a land user’s perception, which in turn will result in certain decisions and actions. As such, these variables can be helpful in understanding what farmers do and not do at a given point in time and can give us some entry points for supporting land users in trying new practices and eventually to adopt agroforestry.

The first limiting factor for the establishment of agroforestry, is that the majority of land users in the Netherlands have never heard of nor seen innovative agroforestry systems in the Netherlands. As such they miss the knowledge and experience to form a realistic picture of agroforestry (influencing their aspirations, beliefs, etc.) and they may feel incapable to become an agroforester (perceived ability).

Secondly, and partly causing the previous, some major structural constraints discourage the establishment of agroforestry, e.g. a lack of research and extension service and the absence of a legal status of agroforestry. Furthermore technical, economic and social aspects may limit the adoption and realization of agroforestry.

The following paragraph sheds a light on these potentially limiting factors (constraints) and discusses ways to alleviate these constraints as well as general favourable conditions (opportunities) for agroforestry.

Agroforestry may have potential for distinctive groups of land users, such as farmers, foresters and small-scale/hobby farmers (depending on rural activities for a minor part of their income). The objectives, constraints and opportunities for agroforestry will probably differ for these three groups. This should be taken into account when designing agroforestry systems. Paragraph 8.3 focuses on the design of agroforestry systems and suggests (as an example) several different management practices for each group.

Finally, paragraph 8.4 will give conclusions on the potential of agroforestry as an innovative and sustainable multiple land use system in the Netherlands.

8.2 Limiting factors and solutions for the adoption of AF

8.2.1 Lack of basic knowledge and skills

In the Netherlands, farmers and estate-owners appear to be unfamiliar with the concept of (modern) agroforestry and thus are not aware of its potential benefits. A major reason for this is the virtual absence of agroforestry examples in this country. Production efficiency and specialization are the order of the day. Many farmers have lost touch with the benefits of trees on arable land, like foresters have lost touch with the benefits of crops and grazing
animals in forests. What is more, in the eyes of many farmers trees are disturbing factors, that compete with their crops and hamper field work. This seems to be especially true for the ‘polder-regions’ or open landscape regions, where trees are virtually absent.

Through a lack of knowledge and agroforestry examples, farmers only have wild trees as a reference and only few are aware that certain species under agroforestry management can produce valuable products in less than 25 years. In a similar sense, Dutch foresters may believe that forests offer limited opportunities to plants, other than mosses and ferns. Their tradition is that forests are for producing timber and they may have limited awareness that forests can produce other valuable products as well.

The management of agroforestry is inherently more complex and demanding than that of monocultures and land users may not possess the necessary technical skills. For example, specialized arable or livestock farmers may not be familiar with many forestry techniques and vice-versa. Also the harvesting, processing and marketing of forest products may require new knowledge and tend to be more demanding than the production of agricultural commodities (Section 8.2.3).

Summarizing the above; to give agroforestry a chance in the Netherlands, first of all, land users must be made aware of agroforestry as a potential land use system. To convince land users of the benefits of AF, it will be necessary to provide precise information about possible (dis)advantages of specific AF systems (i.e. species and design) and management practices including calculations on financial investments, labour demands and returns. Even though several of the ecological advantages of agroforestry have been scientifically proven, as long as the economic advantages are not convincing, only few professional land users will be interested to initiate agroforestry.

Practical demonstrations of agroforestry in the Netherlands may be a good tool to change landowners’ perceptions of growing trees on their land and to show that agroforestry can be more profitable than monocultures. If a land user finally takes the step of implementing agroforestry, he should be able to receive information, training and advice on how to establish and manage this new land use type. The establishment of innovative agroforestry systems may thus be positively influenced through effective promotion, consisting of:

- awareness raising and information on the concept of agroforestry
- demonstration, training/education and information on the management of AF
- adequate advice and support in the establishment of new agroforestry systems

### 8.2.2 Structural constraints
As explained in Chapter 1, developments after the second world war targeted at separation of functions as forestry and agriculture. Since then, the related institutions have focused rather rigidly on the established disciplines and activities (i.e. forestry and agriculture), which hampers the establishment of agroforestry. The structural constraints include a lack of appropriate research and extension services, and discouraging government policies.

#### 8.2.2.1 Research and extension
At present, the lack of a basis for effective promotion of agroforestry, namely an adequate research base and a network of researchers, teachers, extension workers and practitioners, constrains agroforestry development and adoption in the Netherlands. Newman and Gordon (1997) argue that, apart from the farmers’ perception, the perception of ‘land use specialists, extension agents and advisers’ (negatively) affects the development of agroforestry. This holds for the Netherlands as well.
Similarly to farmers, researchers and extension workers are usually specialized and lack the interdisciplinary approach that is required for agroforestry. Ten years ago, Nair (1993) indicated that ‘the reluctance of the academic community to encourage and reward interdisciplinary, applied research, and the lack of funds and infrastructure for conducting such research are major disincentives to scientists and laboratories interested in such fields’. Nowadays the scientific world seems to be more aware of the necessity of interdisciplinary applied research as a basis for sustainable land use in the future. Despite this, in Europe and the Netherlands there is still little attention (also in terms of funding) for agroforestry, which explains the lack of agroforestry research (Wiersum pers.comm. 2004, Forest and Nature Conservation Policy Group, Wageningen; Oosterbaan pers.comm. 2004, Alterra, Wageningen; Mayus pers.comm. 2004, Crop and Weed Ecology Group, Wageningen).

Similarly to the situation of specialized land use systems in the Netherlands, extension staff is usually specialized with respect to the common systems and lacks the skills and tools to address agroforestry issues. There will always be some innovative landowners, that will implement agroforestry anyhow and learn by trial and error. However, for the establishment of agroforestry at a large scale, finally a shift in the organizational structure of extension organizations towards multidisciplinary service is required.

8.2.2.2 Governmental policies

In the Netherlands, governmental policy is more and more aiming at an extensification of the current agricultural systems, leaving more room for nature and thus increasing biodiversity. Nowadays, farmers are subsidised for extensive pasture management or natural management of field borders to increase biodiversity. Former agricultural lands are “developed” into nature and millions of Euros are invested in the connection of natural areas by means of natural corridors, the so called “Ecological Main Structure”. Within this framework AF would fit perfectly, particularly as a gradual transition between natural areas and agriculture. Furthermore agroforestry systems could be an environmentally sound alternative to the over-production of food crops and produce valuable timber and biomass to fulfil the needs for bioenergy. Nevertheless, both the current grant-regulations and the law often discourage the establishment of innovative agroforestry systems.

Subsidy system

In most European countries, including the Netherlands, the integration of trees and arable agriculture is currently unattractive to farmers, because the available subsidy regulations are designed for either forestry or agriculture. A mixed or combined status for agroforestry plots is currently not available in the Netherlands (see also Section 3.3.2). This discourages AF, as (in most cases) agroforesters can neither receive the grants for forestry plantations, nor those for agricultural crops. Crop grants may be available, when the crop field has a minimum width of 20 m (Repelaer pers.comm. 2004, Hoenderloo).

Regarding the dependence of Dutch farmers and foresters on subsidies, adjustment of the subsidy system will be essential to give the establishment of agroforestry equal chances to that of agriculture and forestry. In this sense, also a change in perceptions among policy makers should be achieved; i.e. make the political arena aware of the potential benefits of agroforestry and the necessity to acknowledge agroforestry as a ‘legal’ form of land use and adjust regulations accordingly.

Besides, governmental support in the form of establishment grants and compensation payments for initial revenue losses should partially accommodate the risks and consequently greatly reduce the importance of investments as a constraining factor. Government support could accommodate the initial establishment of modern agroforestry systems in the Netherlands, which can serve as a test ground of agroforestry and fill the gap of empirical proof and practical demonstration in the Netherlands. This may support a further shift of land users towards agroforestry applications.
Nowadays, in several regions of the Netherlands, grants for tree planting are available and might be applicable to very specific AF designs (see Section 6.2). This implies that at present only those specific AF systems may be viable and attractive and only in certain regions. Grants on high-stem orchards for example, are only available in regions where these systems were traditionally found, e.g. in the Betuwe area. Moreover, these grants are usually bound to a maximum budget. For the widespread uptake of AF more grants and with a wider application should be made available.

To give agroforestry systems an equal chance to common agricultural and forestry systems, SAFE (2004) proposes an European “agroforestry status should be considered for the countries where tax policy and grant availability is dictated by land-use classes”, such as the Netherlands. Policies for agriculture and forestry grants should recognize that both silvoarable and silvopastoral systems are ‘legal’ forms of land use which should be permitted to be on a ‘level playing-field’ with conventional agriculture or forestry. On January 1 2005, a new Common Agricultural Policy will be enforced in the European Union. There is a chance that AF will be recognised and promoted by the new CAP, not at least due to the recent achievements in ‘agroforestry policy’ in France, the scientific efforts of the European project SAFE\(^{10}\) to identify the conditions under which agroforestry could be environment-friendly and economically profitable and the recommendations with respect to land use regulations given by a mixed group of European agroforesters (SAFE 2004).

Legal system
In the Netherlands, the legal system does not recognize agroforestry as a land use class. Consequently legal matters discourage the planting of trees on arable land. If trees are planted on arable land, the land usually is classified as forest, which means that the value of the land decreases. Landowners have to ask for permission for the felling of trees on their land and trees must be replanted after felling. A dispensation of the obligation to replant trees after felling can be provided by classifying the plantation as ‘temporary forest’ (LNV-loket 2004). However, the status ‘temporary forest’ has a maximum life time of 40 years, which limits the use of trees with a long life cycle. Since the municipal and regional authorities provide the dispensation, AF may have more potential in one municipality/region than in another. The recognition of AF as a ‘legal’ form of land use and the ‘definition’ of related regulations would probably make agroforestry, in particular the planting of trees with a long life cycle, attractive to farmers.

8.2.3 Other socio-economic factors

Investments and labor
The costs of establishment and maintenance of AF systems may be high and there may be a considerable time-lag before the system, particularly the tree compartment, gives good returns, leading to initial revenue losses. This may be especially a constraint for farmers, used to regular returns from their crops or animals. In a survey about agroforestry (Chapter 7), farmers indicated that they would give preference to fast growing species as poplar and to species that provide products in the short term such as fruits. This choice may be due to the fact that farmers are not acquainted with the possible benefits of slower growing hardwood species. It can be expected that soundly based information and agroforestry demonstration plots may stimulate land users to reconsider their attitude towards long term and risk management and may motivate them to set-up an agroforestry field.

\(^{10}\) Silvoarable Agroforestry For Europe (SAFE 2004)
Apparently (Chapter 7) subsidies on investments and maintenance will directly change a landowner’s perception of risk and make the implementation of agroforestry much easier. As an alternative to subsidies, in the survey it was proposed to reduce the risk of long term investments by means of agreements, that guarantee a minimum timber-price at the time of tree planting. The agroforester receives a fixed price per tree, independent of log volume, when the trees are felled after a certain agroforestry period. Government and private companies could play a role in the development of such agroforestry contracts, which, in view of the growing demands for quality timber and biomass, could benefit both parties and greatly stimulate agroforestry.

A further suggestion was to let companies plant, manage and harvest trees on farms in exchange for good compensations (i.e. tree value). This would lay the responsibility and the related risks of the tree compartment by the external agent. In such cases, the farmer needs neither new skills, nor additional labour or investment. It is uncertain how many farmers would really accept other people managing part of their land and whether satisfactory agreements can be reached.

Also the requirements for labour and the properties of the labour market can play a decisive role in the adoption and design of agroforestry. Apart from the necessity to invest time and effort in acquiring new labour skills, farmers have clearly expressed the fear that agroforestry systems would require more labor. Moreover, the reaction of contract-laborers to the work in agroforestry situations may be of importance and requires further research. Land users' perceptions and, hence, the adoption of agroforestry would be positively influenced, if it could be shown that certain types of agroforestry require less labour and/or that labour is more spread and required in otherwise quiet periods.

An opportunity to reduce labour demands of the tree component may be to plant (coniferous) ‘nurse’ trees along the tree lines or high growing intercrops to train straight crop trees and hence minimize the time needed for pruning. Furthermore the ‘nurse’ trees may also reduce the establishment of weeds in the tree strips and help in reducing wind speed. Planting of Christmas trees as nurse trees could be done mechanically, otherwise the initial planting of nurse trees will require more labor.

Markets
The success of agroforestry may depend on the development of new markets or the expansion of existing ones and effective marketing by the agroforester. This holds for both the wood products and the secondary tree products and innovative intercrops. Most farmers will have no knowledge of the marketing of wood products and what is more, they may be disadvantaged by the small scale of the operation. Also the cultivation and marketing of other crops than the conventional agricultural crops in most cases will be new. In a similar way, foresters may not be used to the marketing of agricultural or secondary forest products.

The relevance of this issue will vary among landowners and among agroforestry systems. The type of AF and its type of products should match the agroforester’s interests/objectives and ideally fit the farm scale. Intensive farmers may not want to invest in marketing skills and thus prefer to cultivate conventional crops as intercrops. Innovative and/or smaller farmers may be more open to development and marketing of products and hence to innovative AF systems with alternative intercrops. Ecological farmers may have the advantage that certain innovative agroforestry products could be sold easily within the alternative circuit. Local or regional market features can play a role as well. Agroforesters near cities or in tourist areas for instance, may have more options for marketing agroforestry products or obtain benefits from recreation. In this sense, the regional location could to a certain extent determine the market feasibility and thus the potential of agroforestry.
Cooperation among farmers and between farmers and foresters may lead to more effective marketing, increasing the viability of agroforestry. To promote agroforestry on a big scale and to open up markets, it may be an idea to make consumers aware of the environmental advantages of agroforestry above conservative agriculture and to introduce a special agroforestry trademark, comparable to the ones that exist for ecological and free-range products.

For the establishment and maintenance of agroforestry, future agroforesters will also be dependent on what markets can offer with regard to planting material and equipment. If, for example, good planting stock or (reasonably priced) picking machines for walnuts and chestnuts are not available, this could mean serious limitations to the adoption of silvopastoral systems with these trees.

Cultural factors
The survey suggests that farmers in ‘tree-rich’ regions and farmers from regions with rather open landscapes, may perceive trees differently. Farmers in traditionally open landscapes may perceive trees as ‘polluting’ the view and reducing its landscape value, whereas farmers in ‘tree-rich’ regions are often used to cope with trees on their farms and feel more sure about skills related to tree-management. For the latter, trees are of cultural-historical significance and have a landscape value. This indicates that the local cultural background and environment may greatly influenceland user’s perceptions on agroforestry as a potential land use system. It could imply that the adoption of AF may be more easy in ‘tree-rich’ regions.

8.2.3 Practical limitations
Even if the major aforementioned socio-economic problems are solved, practical issues, i.e. biophysical factors and technical aspects, can limit (certain) agroforestry applications in certain situations and hence will determine both the adoption and design of agroforestry system.

Biophysical factors
In the previous paragraphs it was described that certain regional features, e.g. cultural traditions, local regulations or markets, may influence farmers perception and hence the potential of agroforestry. More directly regional biophysical characteristics may affect the potential adoption of agroforestry, and the options for inclusion of plant and tree species in agroforestry systems.

The prevailing soil quality may affect farmers’ interest in agroforestry as an alternative land use system. In regions with good soils, farmers generally still make a reasonable income from agriculture. In the geologically poor regions, for instance the sandy regions and the peat soils of the Veenkolonien, farmers are more likely to perceive difficulties in making a living from agriculture and may thus be more inclined to participate in alternatives to diversify their income.

What is more, forestry practices are traditionally found mostly in the geologically poor (sand/peat) regions of the Netherlands, which are generally less suitable for intensive agriculture. A majority of the estates in the Netherlands is actually located in these areas. As estate owners and other foresters form another major group of potential agroforesters, this further underpins the expectation that agroforestry in these regions has a greater potential.

On the other hand, if it can be demonstrated that certain AF systems on good quality soils give better returns than the conventional mono-cropping system, land users in these areas may still be interested to shift to AF. Even though agroforestry may be more interesting for landowners in poor regions to increase and/or diversify income, it must be taken into account
that the prevailing biophysical environment always present a certain limitation to the choice of species. For instance, certain fast-growing trees (e.g. poplar) and other demanding tree- and intercrop-species may be unsuitable for regions with poor soils. Similarly, also maritime exposures can greatly reduce agroforestry options, as many plants and trees cannot withstand the strong and salty sea winds.

Summarizing, agroforestry systems may be not successful in all Dutch regions and the agroforestry design should be adapted to the local soil and climatic characteristics to attain maximum benefits.

Mechanization
The possibilities of mechanization will play a major role in the viability of AF, especially for farmers wishing to grow standard annual crops in the alleys. Therefore agroforestry designs should be adjusted to their machinery. Also possible future purchases of machinery should be taken into account, since trees are bound to their place. This means that the distance between the tree lines should leave enough space for the largest (in width) machines or even a multiplication of that width. In addition a buffer strip between the tree lines and the machinery of 0.5 to 1.0 meters should be considered. For root/tuber crops this distance may be bigger (e.g. 2.0 m) to allow for harvesting without damaging the trees (Mayus pers.comm. 2004, Crop and Weed Ecology Group, Wageningen).

Farmers may prefer large distances (above 20-25 m) above small distances, both for the efficiency with machinery and to diminish shade-effects in order to maintain a healthy intercrop of light-demanding conventional crops. Also the headland in the design should be adjusted to the machinery in such a way that the farmers can easily make turns at the end without loosing valuable time. Related to this, farmers have suggested that large fields would be more suitable for AF. Small fields may be too inefficient in term of labour and land use.

On the other hand certain farmers may be open for agroforestry designs with a closer spacing and/or that need little mechanization and more hand labor, if the returns make up for the extra costs of labor.

8.3 Opportunities for the wider adoption of AF: Matching design and agroforester

The previous paragraph has outlined the major problems constraining the establishment of agroforestry, as well as ways to counteract these constraints. Despite the current constraints, the opportunities for agroforestry development are promising and the technical solutions are seemingly available.

Hence to promote agroforestry effectively, we need to develop and demonstrate agroforestry systems that match different types of land users. Naturally, the factors influencing the decision to establish an agroforestry field or not, can vary a lot between individuals. It can be assumed, that within a distinctive land user group (as estate owner, farmer, forester, hobby farmer) the variables shaping the reception of agroforestry are (to a certain extent) similar. This section will shed a light on the prospective of agroforestry for some major groups of land users. Three major groups of potential agroforesters are distinguished, namely farmers, foresters and small-scale/hobby-farmers.

To give an idea of possible innovative designs, adapted to the local conditions and the individual wishes of the future agroforester, for each land user group one or more possible
scenarios will be given. It must be kept in mind that these are meant as example; no calculations were done on the optimum tree density, and the design may not be optimal. Also subsidies and markets were not taken into account.

8.3.1 Farmers

Farmers are the biggest group of ‘potential agroforesters’ in the Netherlands, considering the area they have in use. For farmers silvoarable and silvopastoral systems are the most logical choice. Firstly, a silvoarable and silvopastoral system can be designed such, that the farmer can apply his common machines. Secondly, they can be easily integrated into their farm management. In this way, the shift from agriculture to agroforestry is smooth. The farmer can continue with the usual crop rotation on the agroforestry field for several years, depending on the design. This means that at the establishment phase only the tree component requires new skills. At a later stage, when trees are tall, the farmer might grow shade tolerant forage and/or intercrops or stop cropping.

Innovative farmers may want to optimize the AF system using new crops and are ready to invest in new cultivation and marketing methods. Despite the larger efforts and higher risks, the cultivation of specialty crops may be more profitable, particularly when the trees are tall. Well chosen species may i) be better adapted to the agroforestry environment, ii) require labour out of the season, and iii) produce valuable products for niche markets.

Also farmers who maintain their standard crop could consider to grow a shade tolerant or specialty crop on the tree strip, e.g. Christmas trees, fruit shrubs, flower bulbs, decorative florals, mushrooms and flowers for honey production. Otherwise the tree strip could be kept bare (and free from weeds) by spraying, mowing or mulching or left as fallow. The first is an expensive solution the latter may lead to contamination of the intercrop by weeds, pests and diseases.

Finally crops for the production of non foods, as fiber and biomass, seem to have good prospects and show high potential for agroforestry applications, in particular for intensive farms.

With regard to the woody component, most farmers would prefer trees with early returns, either from wood or secondary products (Chapter 7). Hence fast growing species or species that yield products as fruits, nuts and other products seem reasonable options. Also tree thinning may generate early income.

Cooperation amongst farmers and cooperation between farmers and foresters may help to combine interests, knowledge and skills and could support the realization of agroforestry. Likewise cooperation between farmers and institutions like state-forestry or nature organizations may be very useful.

Below, several agroforestry scenarios are sketched for farmers. Simple designs of silvopastoral and silvoarable systems, including just one tree species (e.g. walnut, poplar or cherry) and one crop species (e.g. grass, a cereal, maize or vegetables) may be most easily to adopt for large farms. Most research until now has focused on such designs and clear examples can be found in various sources (e.g. SAFE 2004, Oosterbaan et al 2004, Garrett and McGraw 2000, Clason and Sharrow 2000, Dupraz and Newman 1997, Williams et al 1997). Although simple designs are easy to manage and easy to investigate, possibly more benefits can be gained when a system comprises more than one tree and or crop species and/or when the choice of the intercrop over time is adapted to the changing agro-ecological circumstances within the system. Therefore the below proposes slightly more complex designs. These designs are more challenging and may be more labour intensive. It must be understood that these are just proposals for innovative designs and that their value has not been proven. Moreover they may be not so attractive to highly mechanized intensive
farmers, but rather to innovative farmers, interested not only to optimize the farm economy, but also the farm ecology and diversity. Considering the current lack of subsidies on agroforestry systems however, they may well be more profitable than common simple designs.

Agroforestry scenario 1
Silvoarable system comprising poplar, fodder crops and small fruits

Farmers profile
- the farmer prefers a fast returns from the tree compartment, but would also like to harvest a high quality log to add to his pension or to build up capital for the next generation.
- the farmer prefers to maintain a fodder crop as long as possible to feed his livestock and to get rid of the livestock’s dung
- if revenue losses of (part of) the grain intercrop appear to become too high, the farmer is open to alternatives that are more economical

Environmental and technical conditions
- the soil is moderately rich and moist, but well drained
- the farmer has/uses a sprayer of 15 m width
- a minimum distance of 1 m is kept between the tree and the intercrop

The agroforestry design and management practices

Establishment and early agroforestry phase:
- chosen is for a good yielding poplar cultivar, which preferably comes late into leaf
- the orientation of the tree rows is north-south to minimize shade effects on the intercrop and to form a buffer from the western wind
- the distance between tree rows is 32 m, allowing for 2 runs with the 15 m sprayer and a 1 m buffer strip on either side of the trees (width of the tree strip is 2 m)
- the tree to tree distance within a row is 5 m to make up for the large between row distance
- between every two trees within the tree rows one shrub of gooseberries or black currents are planted
- the initial intercrop may be a rotation of any fodder crop, e.g. fodder beets, silage maize, grass and cereals; the intercrop width is 30 m. For fodder beets a larger distance between tree and crop (2 m) may be needed for harvesting, making the intercrop width 28 m for fodder beets.

Second agroforestry phase;
- after 5 – 8 years the crop yields adjacent to the tree line becomes low through shade. Therefore the intercrop width is restricted to 15 m, allowing for one run with the sprayer
- the distance between the trees and the intercrop is now 8.5 meters on either side and the entire tree line strip has a width of 17 m. It is chosen to grow shade-tolerant varieties of gooseberries and black berries on the tree strip which is more or less shaded during the day.
- 2 rows of gooseberries and black berries are planted at 3.5 and 6.5 m from the poplars, with a distance of 2 m within the row. This leaves enough room for the development and picking of the berries
- from now on the intercrop strip is only planted with either fodder beets, grass or cereals. Maize may cast too much shade on the berries
- during the whole cycle the poplars are regularly pruned to prevent knots and to reduce shade effects and problems with the machinery

**Harvest and yield expectations**
- at year 20-25 the poplars are ready to harvest
- the first planted berries will start producing after 2 years (year 8) and achieve full production at year 10
- all crops will produce until year 20-25, when the poplar logs are harvested

**Alternative options for management**
- planting poplar at 3 m within the row and thin later
- plant fast growing ornamental trees as pussy willow or curly willow within the poplar rows and/or along the poplar rows. The branches can be harvested after several years and sold to the floral industry for early profits, will suppress weeds and may reduce pruning costs
- plant flowers such as daffodils within the tree rows. These will give little competition, are adapted to partial shade and will provide additional income
- replace light demanding fodder crops with leafy vegetables as soon as shade becomes too strong
- instead of decreasing the intercrop strip at once from 30 to 15 m, this could also be done gradually, if the machinery can be adapted to intermediate widths

**Remarks**
- possibly at a certain age the poplars will start casting to much shade for the narrow intercrop strip or even for the berries/currants. A solution may be either to plant in a wider pattern, to thin and/or prune the poplars to decrease shading, to change to more shade tolerant intercrops or a combination of several of these options.

**Agroforestry scenario 2**

**Silvoarable system comprising walnut, food crops and hazel**

**Farmers profile**
- the farmer prefers a fast returns from the tree compartment, but would also like to harvest a high quality log to add to his pension or to build up capital for the next generation
- if revenue losses of (part of) the intercrop appear to become too high, the farmer is open to alternatives that are more economical

**Environmental and technical conditions**
- the soil is a moderately rich and well drained open soil
- the farmer has a sprayer of 18 m width
- a minimum distance of 1 m is kept between the tree and the intercrop

**The agroforestry design and management practices**

**Establishment and early agroforestry phase:**
- an early bearing walnut cultivar is planted at 20 m x 7 m, allowing for one machinery run with the 18 m sprayer and a one meter buffer strip on either side of the trees
- within the row between every 2 walnuts 2 shrubs of hazelnuts are planted, at 2.5 m from the walnuts
- the orientation of the tree rows is north-south to minimize shade effects on the intercrop and to form a buffer from the western wind
- the initial intercrop may be a rotation of any crop, e.g. vegetables, silage maize or cereals with a width of 18 m and tuber crops as potatoes, sugar beets, fodder beets with a width of 16 m (larger distance between tree and crop needed for harvesting)
- after several years only leafy vegetables are planted as intercrops, to minimize underground competition with the walnuts, which could delay nut production

Second agroforestry phase:
- at year 7 three double rows of hazelnuts are planted to substitute the annual intercrop. The centers of the double rows will be located at 5, 10 and 15 m from the walnuts. The hazels will be spaced 2 x 2 m within the double rows
- the whole agroforestry plot will be under sown with a grass-clover mixture, which is most useful for mechanical picking and can be harvested as hay or silage
- during the whole cycle the walnuts are regularly pruned to establish a straight stem and to reduce shade effects and problems with the machinery
- it may be necessary also to prune or even coppice the hazels regularly to maintain enough space for machinery.

Harvest and yield expectations
- after 7 to 8 years the walnuts start producing commercially. The nuts can be mechanically harvested on the pasture that will be well established in the autumn of year 7
- crop yields till year 7, then yields from vegetables
- the hazels will be commercially bearing in year 4/5. The double rows will then be 3 m wide, leaving 2 m between the rows for harvesting equipment
- the hazels and walnuts will be productive until year 50, when both are harvested

Alternative options for management
- hazels may also be substituted by Buckthorn (*Hippophae* spp.) or Azerole (*Crataegus azerolus*)
- walnuts may also be planted at 3 m within the row and be thinned later
- plant Christmas trees in the tree line and along trees. These can serve as nurse trees, forcing the walnuts to form straight logs and reducing pruning costs. They can be harvested after 5-10 years and replaced by shade-tolerant species

Remarks
- it may be worthwhile to apply organic cultivation methods as soon as the hazels are planted, since hazels produce well without fertilizers and pesticides and thus the products will gain an additional value

Agroforestry scenario 3

Silvoarable system comprising wild cherry and small fruits

Farmers profile
- the farmer is a fruit grower and is interested to try an alternative for the standard short- and medium-stemmed orchards

Environmental and technical conditions
- the soil is a rich and moist sandy clay soil and well drained

The agroforestry design and management practices

Establishment and early agroforestry phase:
- A cherry cultivar with good fruit production and good log production is planted at 7 m x 7 m.
- Between each 2 cherries in the row, 2 bushes of black currants and gooseberries are planted.
- *Cornus canadensis* is planted within the row to form a productive groundcover, meanwhile decreasing the need to weed.
- At a 5 m wide strip between the cherry-rows a crop of strawberries is planted.
- Netting is stretched above the trees to protect the fruits from being eaten by birds.

**Second agroforestry phase:**
- After 4-5 years the strawberries are replaced by a double row of black currants and gooseberries.
- During the whole cycle the cherries are regularly pruned to establish a straight stem and to reduce shade effects and problems with the machinery.
- Grass is mown regularly to obtain silage feed and to reduce competition and pests.

**Harvest and yield expectations**
- The cherries will come into commercial production in the fifth year.
- The first planted berries/currants will get productive in year 3.
- The *Cornus* will be productive from year 2 and may be sold as specialty products.
- The later planted berries/currants will get productive in year 8/9.
- After 40 years the cherry trees are ready to be harvested and sold as high quality wood.

**Remarks**
- The berry-crops may get less productive at a certain moment due to their age. One option is to substitute them by young plants of the same species or by other (even more) shade-tolerant species. Another option is to substitute them by grass. At that moment the cherries may be strong and high enough to prevent livestock from damaging them.
- The *Cornus* may need regular pruning to prevent them from encroaching onto the other intercrops.

**Agroforestry scenario 4**

**Silvoarable system comprising alder standards, grass forage and willow coppice**

**Farmers profile**
- The soil is rather wet clay or peat soil, with a high ground water table.
- Fields are bordered by drainage ditches.
- Instead of buying more milk-quota, the farmer prefers to sell some and invest it in diversifying his farming system.

**Environmental and technical conditions**
- The soil is rather wet clay or peat soil, with a high ground water table.
- Fields are bordered by drainage ditches.

**The agroforestry design and management practices**

Establishment and early agroforestry phase:
- Rows of black and red alders are planted at 10 m x 2 m in the grass sward, in the direction of the ditches and bordering the ditches.
- the grass in the alleys is regularly cut as silage

Second agroforestry phase:
- after 2-3 years, when the alders are well established, willow cuttings are planted in the alley
- the willows will be coppiced every 3-4 years to produce biomass

Harvest and yield expectations
- the alder standards can be harvested after 20-40 years and sold as valuable veneer
- after that they may be either left to resprout to produce new standards after thinning, or used as coppice for biomass as well
- after about 20 years, when the growth potential decreases, the willow coppice must be replaced by new cuttings

Remarks
- the willow coppice can be used to produce heat (e.g. for the homestead or a glasshouse) or electricity on farm, be processed at a cooperative or be sold to other parties
- the willow branches may also serve as woody ornamentals or can be processed into baskets and other valuable products

8.3.2 Foresters
Foresters may be private foresters (e.g. estate owners or farmers with a patch of forest) or forest managers working for institutions as state-forestry or nature organizations. For pure foresters the adoption of forest farming practices seemingly is the most simple and logical option. Estate owners who also practice agriculture may have other interests and needs, similar as those described in Section 8.3.1. The design also depends of the initial situation, i.e. bare land or established forest.

As for farmers, the design should be adjusted to the owner’s interest and willingness to take risks and to invest in new knowledge and markets. The majority of the specialty crops mentioned in Section 5.4 may well fit in a forest farming design. Many of these may produce very valuable products for niche-markets. Further value may be added by processing these products.

A possibly less demanding option may be the production of free-range meat, e.g. chickens, turkey, pigs and deer.

Agroforestry scenario 5

Forest farming system comprising hardwood species and wild simulated ginseng

Forester’s profile and site conditions
- a forest owner already has (semi-)natural forest, which he would like to generate more income, but preferably with little efforts
- the estate owner has the means to do long term investments and can take some risk of failure
- the soil is a natural humus-rich and well drained forest soil

The agroforestry design and management practices
the existing forest is thinned in autumn to make room for ginseng cultivation and to achieve 70-80% shade. Slow growing hardwood species are maintained.
- beds where the ginseng is to be grown are marked with downed tree trunks.
- the leaf litter and competing understorey plants are removed.
- topsoil (10-15 cm) is harrowed and stratified seeds are planted 1 cm deep in the beds in rows 45 cm apart and 10 cm within the rows.
- seedbeds are covered with the removed leaf litter.

**Harvest and yield expectations**
- seeds can be yearly harvested after year 4 and either sold or used for sowing new seedbeds.
- ginseng roots can be harvested after 10-12 years, after which a new cycle can be started.
- ginseng can be sold as wild simulated ginseng and hence earn a good price.

**Remarks**
- it is unknown how ginseng will grow under Dutch circumstances.
- if the root is of lower quality, profits of the system may be considerably lower.

**Scenario 6**

**Forest farming system comprising hardwood trees, sugar maples (syrup), chestnuts (nuts) and gourmet mushrooms**

**Forester's profile and site conditions**
- a forester already manages a (semi-)natural forest on a rich sand, which he would like to generate more income.
- the forest owner is interested to produce valuable specialty products for niche-markets.

**The agroforestry design and management practices**
- the existing forest is thinned and only slow growing hardwood-species are maintained.
- hardwood stems form the thinning are inoculated with shii-take spores and placed between the trees.
- on open spots sugar maples and chestnuts are planted.

**Harvest and yield expectations**
- after 9 months the first mushrooms can be picked.
- after 8-10 years the first chestnuts can be picked.
- after about 15 years the sugar maples are big enough to be tapped.
- shii-takes, chestnuts and maple-syrup can be sold to local shops, restaurants and on the biological market, directly or as processed products.

**Alternative options for management**
- if the forest is fenced pigs, deer or turkeys may be introduced to produce valuable meat for the biological market.

**Remarks**
- it is unknown sugar maple will produce much syrup under Dutch circumstances.
Otherwise it still produces a valuable hardwood.
8.3.3 **Hobby/small-scale farmers**

Last but not least, agroforestry may offer very interesting features for the increasing group of small-scale and hobby land users. As this group can take greater risks, they may be more open to innovative land use strategies and to adopt agroforestry. Moreover, this type of land user could afford to go new ways of farming which offer more than direct economic advantages. They may serve as an example for more conservative conventional farmers and foresters. However, also here counts that these people should first be made aware, informed and trained with respect to agroforestry.

Depending on the possibilities and wishes, this heterogeneous group may apply any of the innovative agroforestry practices mentioned in Section 2.4, most of which were given examples of in the previous Sections on farmers and foresters. Particularly interesting for hobby-farmers, are forest gardening systems, which can provide timber, fuel, a variety of food, flowers, medicines and other products for home consumption or marketing. Forest gardening designs can be fully made according to the wishes and creativity of the forest gardener. They may comprise a limited number of species in practical arrangements, but may also be a seemingly unorganized mix of numerous species, resembling the structure of a natural forest. Below one example of a possible forest gardening scenario is given.

**Scenario 7:**

**Forest gardening system comprising a multifunctional mix of tree and crop species**

**Landowners’ profile and site conditions**

- the owner has a patch of pasture and an old orchard with high-stem apples and pears
- he would like to turn this into a system, which is visually pleasing and produces a variety of food and other products for the family, and maybe some for selling
- he has enough money and time to invest in setting up the system

**Environmental and technical conditions**

**The agroforestry design and management practices**

**Establishment and early agroforestry phase:**

- along the western side a hedge of red and black alders, willows and Christmas trees is planted, to reduce wind speed and to produce timber, firewood, twigs for baskets and Christmas trees for selling
- the pasture is planted with rows of walnuts, chestnuts, plums, robinia, strawberry trees, Siberian pea trees, mulberries, juneberries and chokeberries and will form the top layer of the forest garden. At some places the density of the trees is low, leaving open areas for light demanding intercrops.
- the tree lines in the pasture and the orchard are interplanted with lower trees as hazels, willow (coppice), crabapples, *Eleagnus* spp., sea buckthorn, azeroles (*Crataegus azerolus*) and cornelian cherry. Also in the alleys some of these species may be planted, depending on their demands regarding light. They should be planted on spots that are expected to provide good growth conditions, now and in the future.
- under delicate fruits as the strawberry tree and the mulberries, the grass sward is maintained. Amongst the grass spring flowers such as daffodils can be planted to cut and sell.
- on other places the grass may be removed to grow vegetables, herbs, ornamentals and small-fruit
- on open spots in the forest garden, trellises will be established to grow grapes, brambles and kiwi-fruit

Second agroforestry phase:
- when the trees start casting more shade, light demanding vegetables can be replaced by shade-tolerant perennial vegetables, herbs and small fruits
- on places with dense shade, ferns or shade-loving flower bulbs and medicinals may be planted. Logs may be placed to produce gourmet mushrooms
- beehives are placed to pollinate the fruits and to yield honey and wax

Harvest and yield expectations
- the garden directly produces vegetables and fruits from the apple and pear trees
- after several years some of the fruit and nut trees will start producing for home consumption. Perennial vegetables and small-fruit can be used for home consumption or marketing. Mushrooms, flowers and other ornamentals, herbs and medicinals can be harvested for the market. Willows may be coppiced to provide twigs or firewood
- after 8 years most trees will produce plenty fruits and nuts for home consumption and to sell on the market

Remarks
- home processing of fruits, nuts and herbs can generate additional income
- fresh and processed products may be sold on farm or sold to local restaurants, shops or markets
- trees may need to be regularly pruned to maintain suitable growth conditions for other species
- depending on the availability of labour and money, the planting of trees can be spread over several years. This also gives more opportunity to adjust the choice and placement of new trees to the development of the system

8.4 Conclusions

The current agricultural surplus, the decreasing incomes of farmers and the increasing pressure on agricultural land to address more functions than arable production, demands us to take a wider view and to search for alternative and sustainable multiple land use systems in the Netherlands. Agroforestry may be an answer.

Agroforestry systems are very efficient in terms of resource use and could introduce an innovative (agricultural) production system that will be both environment-friendly and economically profitable. As such, agroforestry would fit perfectly to the current governmental policies aiming for an extensification of the agricultural system, leaving more room for nature and thus increasing biodiversity. Agroforestry has potential for various land user groups, as farmers, foresters and small-scale/hobby farmers and designs should be adjusted accordingly.

Growing trees in association with arable crops and/or livestock may improve the sustainability of farming systems, diversify farmers’ incomes, provide new products, and create attractive landscapes for both wildlife and people. Well designed silvoarable and silvopastoral system offer farmers the opportunity to apply common machinery and continue with the usual crop rotation on the agroforestry field for several years, providing sustainability of farm income in the early stage. There is a broad range of shade-tolerant crops, which
could produce valuable products at a later stage, both on a large scale for the bulk market and on a smaller scale for niche markets. Many of these are new for the Netherlands and require further research to assess their potential.

Forest farming systems have potential for private foresters and forest managers working for institutions as state-forestry or nature organizations. The production of shade-tolerant specialty crops or wild meat in existing forest stands may provide them with additional and diversified income. Forest gardening mainly has potential for small-scale and hobby farmers, who aim to cultivate for home consumption or produce a variety of products for the niche market.

Notwithstanding the promising opportunities of agroforestry, there are some important constraints that prevent the realization of the potential benefits. A major constraint is institutional. Agroforestry is not recognized as an official land use status. This discourages AF, as (in most cases) agroforesters can neither receive the grants for forestry plantations, nor those for agricultural crops. National laws oblige farmers to harvest trees before age 40 to prevent agroforestry plots shifting to a forest status and considerably decrease in value. Local regulations may impede the planting or felling of trees or force farmers to replant trees after felling.

Until now, there has been little attention (and funding) for agroforestry in Europe and The Netherlands. The lack of an adequate research base, practical demonstrations and extension agents and advisers who are able to address agroforestry issues hampers the development of agroforestry, as farmers and other land users often lack the knowledge and skills.

Although the concept is new, farmers in the Netherlands have indicated to be interested in agroforestry as an alternative land use system, if it proves to be economic in The Netherlands. At present only large farms may be able to face the investment costs for tree establishment, unless subsidies are provided for the smaller ones. Apart from the fact that most land users in the Netherlands are not aware of the possibility of agroforestry as an alternative land use system, few will be inclined to adopt it as long as the financial benefits are not proven and demonstrated. Applied research, practical demonstrations and institutional support are recommended to develop agroforestry on a large scale and to realize the benefits it offers.
References


Cannell, M.G.R., Noordwijk, M. van and Ong, C.K., 1996. The central agroforestry hypothesis: the trees must acquire resources that the crop would not otherwise acquire. Agroforestry Systems 33: 1-5.


CRB (Commissie voor de samenstelling van de Rassenlijst voor Bosbouwgewassen), 2002. 7e Rassenlijst van bomen. Lijst van aanbevolen soorten, rassen en herkomsten van bomen voor gebruik in bos, landschap en stedelijk gebied. Stichting DLO, Nederland.


# Appendix: Major approaches to classification of agroforestry systems and practices

## Categorization of systems based on their structure and functions

<table>
<thead>
<tr>
<th>Nature of components</th>
<th>Arrangement of components</th>
<th>Function (role and/or output of components, especially woody ones)</th>
<th>Grouping of systems (according to their spread and management)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Agrisaviculture</strong></td>
<td>In space (spatial)</td>
<td><strong>Productive function</strong></td>
<td>Systems in/for</td>
</tr>
<tr>
<td>(crops and trees incl.</td>
<td>Mixed dense</td>
<td>Food</td>
<td>Lowland humid tropics</td>
</tr>
<tr>
<td>shrubs/trees and trees)</td>
<td>(e.g., homegardens)</td>
<td>Fodder</td>
<td>Highland humid tropics (above 1,200 m a.s.l., Maasai)</td>
</tr>
<tr>
<td><strong>Silvo-pastoral</strong></td>
<td>Mixed space</td>
<td>Fuelwood</td>
<td>Lowland subhumid tropics</td>
</tr>
<tr>
<td>(pasture/animals and</td>
<td>(e.g., most systems of trees in pastures)</td>
<td>Other woods</td>
<td>(e.g. savanna zone of Africa, Cerrado of South America)</td>
</tr>
<tr>
<td>tree)</td>
<td></td>
<td>Other products</td>
<td></td>
</tr>
<tr>
<td><strong>Agro-silvopastoral</strong></td>
<td>Strip (width of strip to be more than one tree)</td>
<td><strong>Protective function</strong></td>
<td>Highland subhumid tropics (tropical highlands)</td>
</tr>
<tr>
<td>(crops, pasture/animals, and trees)</td>
<td></td>
<td>Windbreak</td>
<td>(e.g., in Kenya, Ethiopia)</td>
</tr>
<tr>
<td><strong>Others</strong></td>
<td>Boundary (trees on edges of plots/fields)</td>
<td><strong>Soil conservation</strong></td>
<td></td>
</tr>
<tr>
<td>(multipurpose tree lots,</td>
<td>In time (temporal)</td>
<td>Moisture conservation</td>
<td></td>
</tr>
<tr>
<td>apiculture with trees,</td>
<td>Coincident</td>
<td>Soil improvement</td>
<td></td>
</tr>
<tr>
<td>aquaculture with trees,</td>
<td></td>
<td>Shade</td>
<td></td>
</tr>
<tr>
<td>etc.)</td>
<td>* Coincident</td>
<td>(for crop, animal and man)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Overlapping</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Sequential (separate)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>* Interpolated</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Source: Nair 1993)
Attached report: Survey of farmers’ reaction to new to new silvoarable and silvopastoral systems in The Netherlands