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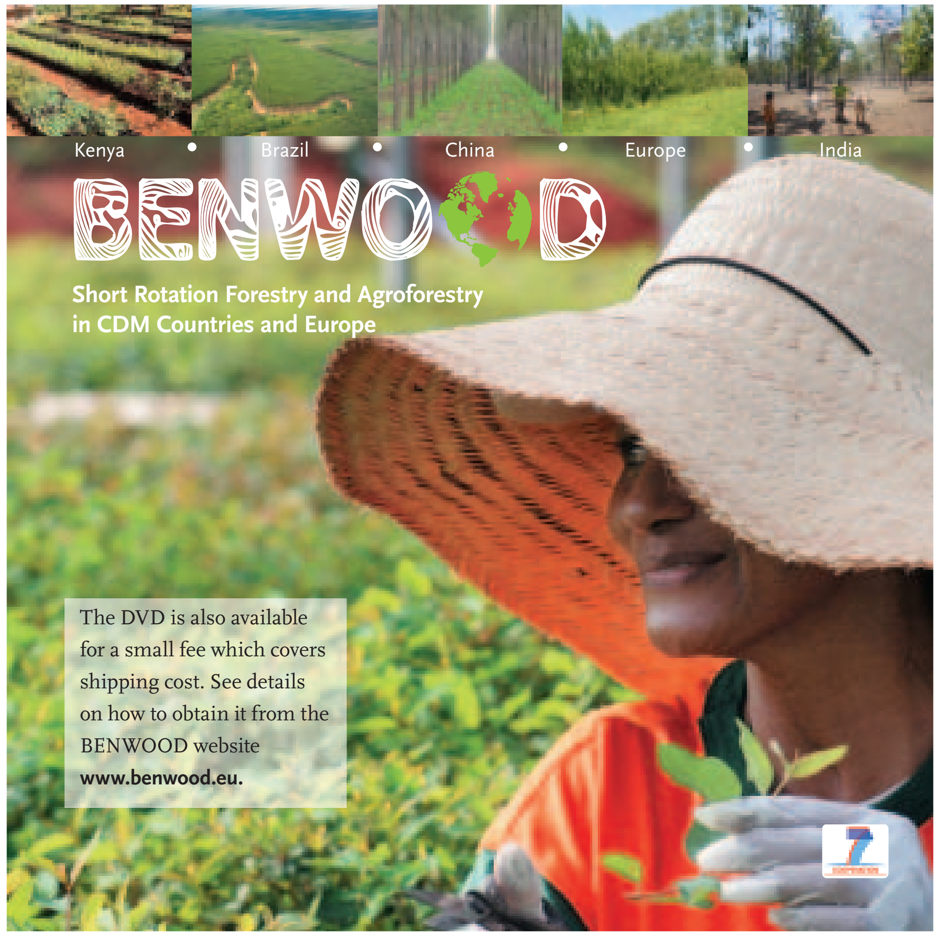
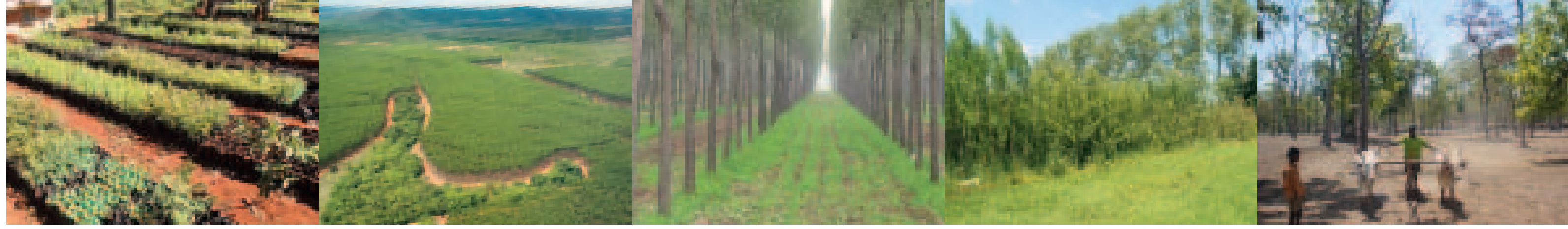
BENWOOD

Short Rotation Forestry and Agroforestry in CDM Countries and Europe

The BENWOOD project is funded by the European Union under the 7th Framework Programme for Research and Innovation





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BENWOOD

Short Rotation Forestry and Agroforestry in CDM Countries and Europe

The BENWOOD consortium

Compiled by
Falko Kaufmann, Genevieve Lamond, Marco Lange,
Jochen Schaub, Christian Siebert and Torsten Sprenger

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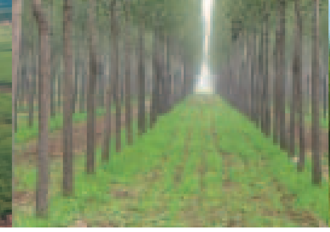

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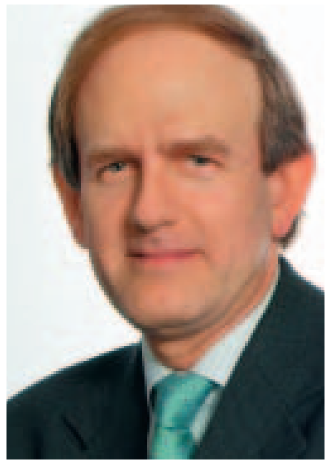
Foreword

As the Head of Unit for 'Agriculture, Forestry, Fisheries and Aquaculture' within the European Commission DG Research and Innovation, I am very pleased to introduce this summarized findings presenting the results of the BENWOOD project.



The BENWOOD project has been funded by the European Commission under the Seventh Research Programme (FP7) Theme addressing 'Food, Agriculture and Fisheries, and Biotechnology' in order to make relevant information on Short rotation forestry (SRF) available to stakeholders. It is particularly timely given the increasing importance attached to ensuring appropriate delivery of research results to the end user as a vital part of the innovation chain.

The work accomplished during the 2.5 years of the project has been outstanding, particularly with respect to the substantial number of stakeholders reached during this period. The objectives listed in the initial proposal, which were quite ambitious, have all been achieved, and in addition other avenues have been explored. This results from the excellent coordination work by Thomas Lewis from the SME energieautark, as well as major contributions from the other project partners who originate from a wide range of countries, including developing countries.

The BENWOOD results present opportunities for participation in various schemes aimed at mitigating climate change by allowing CO_2 emissions in one region to be offset by CO_2 emission reduction in another. The results are important with respect to fulfilling Kyoto Protocol obligations and they will have an effect on industrial policy and investment both in industrialized countries seeking to reduce the cost of generating CO_2 and in developing countries where increased investment will occur. In addition, it should lead not only to increased investment in forestry, but also to increasing markets for equipment linked to biomass processing as well as generating markets for forest products with a focus on biofuel producers.

I hope that the outputs from the project, concentrated in this summarized findings, will help to support a new era for the production of renewable, carbon-neutral alternatives to non-renewable fossil fuels.

I would also like to take this opportunity of expressing a strong wish that the good work of the project does not end when the European Commission funding has finished and sincerely hope that the initiative of continuing 'BENWOOD activities' under the umbrella of FAO in the SREN network (see foreword of Thomas Lewis) will be successful.

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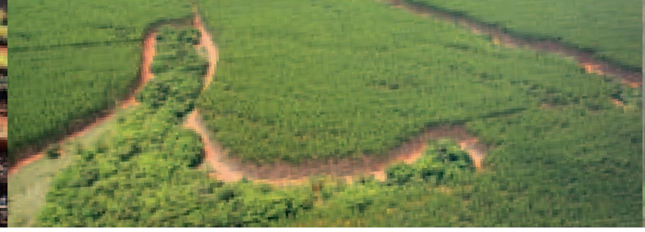

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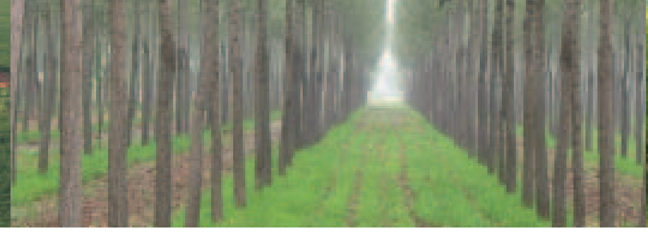

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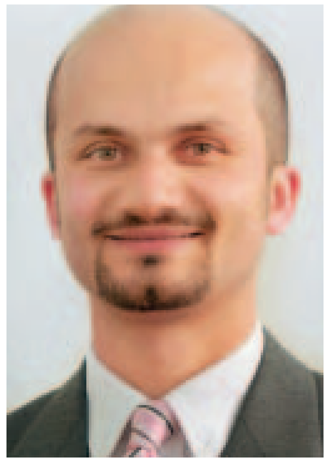
DEAR READERS AND STAKEHOLDERS,



the BENWOOD project has been funded by the European Union (EU) within its FP7 in order to collate information on SRF and make it available to a broad base of stakeholders. BENWOOD project partners are from Austria, Brazil, China, Croatia, Germany, India, Italy, Kenya, Poland, Sweden and the United Kingdom. This summarized findings is a culmination of effort over the previous two years to bring together in a succinct manner and summarize the main findings of the research. The major project outputs can be found on the DVD attached to the brochure and/or can be downloaded from the public BENWOOD website on the following link: www.benwood.eu.

1. **Best Practices of Short Rotation Forestry** – a description of practices focusing on SRF in Europe.
2. **Land Use Management Standards** – a description of issues that may be encountered during project development and implementation with a focus on African case studies.
3. **Guidelines on Short Rotation Forestry** – a synthesis of important considerations when planting SRF for project developers.
4. **Profitability of Short Rotation Forestry from the Farmer's Perspective** – a synopsis of differences between developing and industrialized countries when considering business models, based on case studies from India, China, Kenya, and Poland. Sheds light also on the economic importance of combining annual crops in agroforestry systems.
5. **Guidelines for Project Developers: Information about Cooking Stoves** – an overview of small cooking stoves based on wood fuel and their efficiency.
6. **Biomass Gasification, Options for Local Electricity and Charcoal Production from Short Rotation Forestry** – a report on charcoal making. Charcoal is one of the main cooking fuels in many developing countries.
7. **Research Agenda on Short Rotation Forestry** – a document on the most pressing research issues in the sector.
8. **CDM Specifics** – a document which outlines the characteristics of partner countries which are eligible to host CDM projects, and the current knowledge of SRF in those areas.

Films and photographs

A DVD has been produced and is attached to the hardcopy version of this brochure. It is also available for a small fee which covers shipping cost. See details on how to obtain it from the BENWOOD website. The DVD includes all material too bulky for download; for instance, 2.5 hours of video material and more than 500 photographs.

This summarized findings can be seen as your potential entry point into something that goes on after the BENWOOD project ending (August 2011): To participate in and to contribute to the international exchange of experience please follow the instructions at the BENWOOD website: www.benwood.eu. The website will be integrated by the end of 2011 into the larger network SREN (Sustainable Rural Energy Network: www.petiteenergie.com), which is part of the umbrella network Escorena (European System of Cooperative Research Networks in Agriculture: www.escorena.net. Escorena and SREN were initiated by the FAO (Food and Agriculture Organization of the United Nations). The BENWOOD website will be regularly updated on a voluntary basis with contents by a working group on SRF and contributors are highly welcomed.

Finally, my sincere acknowledgement and appreciation goes to the European Commission – DG Research, Directorate E 'Food, Agriculture and Biotechnology', Unit 'Agriculture, Forestry, Fisheries and Aquaculture' who have made the BENWOOD project possible.

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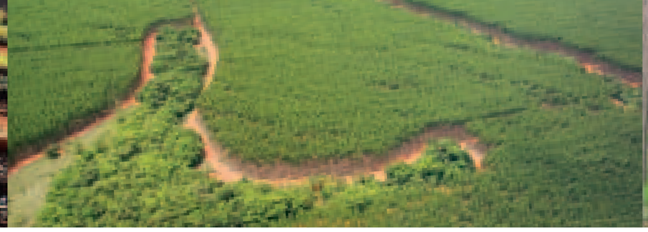

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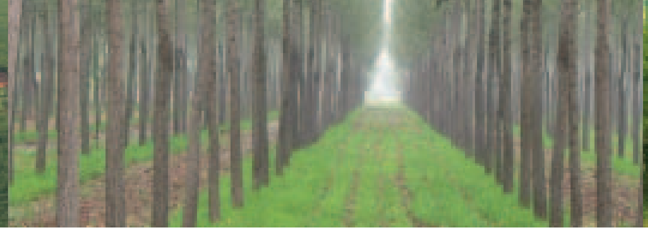

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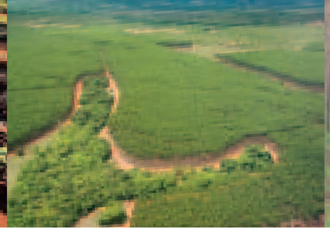

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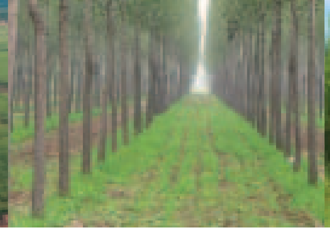

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1. Partners

:: 1.1 ALASIA NEW CLONES (ITALY)

Alasia New Clones is a private company located in Savigliano (North-West Italy). Alasia is the European leader in the sale of cuttings and rods aimed at the establishment of dedicated plantations for producing woody biomass. Its main goal is the development of agro-energetic process chains using tree species (Poplar and Salix) and herbaceous plants according to SRF systems from the field to the final processor. For three generations, the Alasia family has been involved in the research and cultivation of fast-growing species, especially of the genus Populus. Starting in 1983, Franco Alasia initiated an ambitious breeding program and was the only European private company to be doing this kind of activity. The company 'Alasia New Clones' was established to deal with the marketing of Alasia's products in Europe and collaborating with leading research institutes of agriculture and forestry. The main contribution to the EU-funded BENWOOD project outputs has been providing research requirements for new clones and mechanization.

:: 1.2 BANGOR UNIVERSITY, SCHOOL OF ENVIRONMENT, NATURAL RESOURCES AND GEOGRAPHY (WALES, UNITED KINGDOM)

Bangor University is situated in North Wales of the United Kingdom and was founded in 1884. The School of Environment, Natural Resources and Geography (SENRGY) is recognized as one of the leading international institutions in research and education in agroforestry, tropical forestry and forest ecology. Research interests and specialist expertise exist in agriculture, forestry, economics, soil sciences, wood and fibre science and applied ecology. Research mission: to provide a scientific basis for sustainable utilization and conservation of agricultural and forest resources. The School prides itself in strongly interdisciplinary research with close collaboration across the land use, environmental, biological and chemical disciplines. The tasks that SENRGY has been a major contributor to under the EU-funded BENWOOD project have been those focused around giving a developing country perspective of SRF/agroforestry. Major responsibilities have lain in 'CDM Specifics', 'Land Use Management Standards' and providing a case study for the 'Profitability of Short Rotation Forestry from the Farmer's Perspective'.

:: 1.3 BEIJING FORESTRY UNIVERSITY, INSTITUTE OF WOOD-BASED MATERIAL SCIENCE AND ENGINEERING (CHINA)

The Wood-based Material Science and Engineering Institute, established in 2002 by Beijing Forestry University (BJFU) and the Canadian National Wood Industry Technology Research Institute, mainly engages in research and practice of biomass thermal chemical conversion theory, efficient use of technology for biomass thermo-chemical conversion, biomass materials and their functional improvement. The institute has been charged with and completed more than 30 national, provincial or ministerial issues and published more than 200 articles in national and international journals, 10 academic books and facilitated more than 50 doctoral and master theses. The main outputs BJFU contributed to within the EU-funded BENWOOD project were 'State of the art of SRF', 'CDM Specifics' and providing a case study for the 'Profitability of Short Rotation Forestry from the Farmer's Perspective'.

:: 1.4 BIOENERGY 2020+ (AUSTRIA)

With more than 60 scientists, BIOENERGY 2020+ is the scientific backbone of the Austrian biomass industry and one of Europe's leading pre-competitive R&D bodies in the field of energetic utilization of biomass. Its major fields of activities are biomass combustion, biomass gasification (gasification and synthetic biofuels, fermentation and liquid biofuels), and modelling and simulation. The research area of combustion, which covers the majority of the Centre's budget, has four principal fields of interest: (a) development of standardized solid biofuels, (b) development of combustion technology, (c) development of combined heat and power and cooling technology, and (d) system integration and system optimization. The service portfolio of the research centre includes cooperative and contract research, engineering, consulting, trainings and seminars as well as networking activities. The company's headquarters is located in Graz. Within the EU-funded BENWOOD project the sub-task 'research requirements to conditioning and usage of SRF dendromass' was conducted by BIOENERGY 2020+.

:: 1.5 ENERGIEAUTARK CONSULTING GMBH (AUSTRIA)

Energieautark consulting gmbh was founded in 2006 by Thomas Lewis, a physicist, and provides consulting for planning and implementation of energy autonomous systems. This includes the elaboration of integral feasibility studies on heating/cooling, lighting/power and mobility, all on the basis of regionally available renewable energy. Services are provided, in collaboration with partners, for buildings, settlements, municipalities and regions. In addition, energieautark co-ordinates research projects at national and EU level which contribute to the goal of energy autonomous systems. Within the EU-funded BENWOOD project, energieautark was responsible for overarching project coordination and the following outputs: 'Best Practices' and 'Profitability of Short Rotation Forestry from the Farmer's Perspective'.

:: 1.6 KOMPETENZZENTRUM HESSENROHSTOFFE E.V. (GERMANY)

The Federal Government of Hessen aims to raise the proportion of renewable resources contributing to the state's total energy production. To achieve their goals, the federal state government founded HeRo e.V. in 2004 as a centre of competence in Witzenhausen, Germany to contribute actively to the conservation of rural areas and promotion of sustainable energy politics. HeRo is state-controlled by the Hessian Ministry for Environment, Energy, Rural Areas and Consumer Protection which supports research on energy crops including their production and utilization. The six core areas of HeRo are: science and research, production of renewable resources, energy-related and material use, technology and technology transfer, municipal initiatives, and further education. The main tasks of HeRo within the EU-funded BENWOOD project were: 'State of the art of SRF', 'Linking with national stakeholders', 'Coordination and compilation of the Research Agenda' and 'Development of the project´s brochure and DVD'.

:: 1.7 PUNJAB AGRICULTURAL UNIVERSITY, DEPARTMENT OF FORESTRY AND NATURAL RESOURCES (INDIA))

The Punjab Agricultural University (PAU) was founded in 1962 at a time of enormous food shortage. This meant that the key role at the time was not only in making the country self-sufficient in food grains but also enabling it to export agricultural commodities. The university played an important role in ushering in the first green revolution which transformed the socio-economic life of the peasantry of the region. PAU was declared the best agricultural university in the country in 1995 by the Indian Council of Agricultural Research. Again PAU was adjudged country's best agricultural university for the year 2011 and was honoured with the coveted Mahindra Samriddhi India Agri Award 2011. The Indian Council of Agricultural Research has set up two centres of advanced studies at PAU with the Department of Soil Science and Plant Breeding and Genetics. The Department of Forestry and Natural Resources (department of PAU associated with the BENWOOD project) was established in 1978 to impart the extensive knowledge evident in production and management of forestry/agroforestry plantations and to develop suitable agroforestry systems/models for adaptation in different agro-climatic regions.Within the EU-funded BENWOOD project, PAU was the work package leader for 'CDM specifics' and also contributed towards the following outputs: 'Best Practices', 'Profitability of Short Rotation Forestry from the Farmer's Perspective', and 'Land Use Management Standards'. Information dissemination was another major activity during the project period.

:: 1.8 SWEDISH UNIVERSITY OF AGRICULTURAL SCIENCES, DEPARTMENT OF CROP PRODUCTION ECOLOGY (SWEDEN)

Swedish University of Agricultural Sciences (SLU) was formed in 1977 and is the only agricultural, forestry and veterinary university in Sweden with a defined role in society: to take responsibility for the development of learning and expertise concerning biological resources and biological production. The Department of Crop Production Ecology is located in Uppsala, Sweden and is specialized in SRF with regard to all aspects of production and phytoremediation, e.g. abiotics, biotics, cultivation techniques, management, physiology and ecological sustainability. 20 years of research history covers various aspects of biomass growth, phytoremediation and biodiversity and have resulted in several hundred papers and reports, many of which have proven relevant to Benwood. Within the EU-funded BENWOOD project, the main tasks SLU contributed to were: 'State of the Art of SRF', 'Land Use Management Standards', and led the task of compiling the 'SRF Guidelines' based on obtained results of the project.

:: 1.9 THE PLANTAR GROUP (BRAZIL)

The Plantar Group has been working in the forestry industry and its multiple production chains since 1967. The group offers products and services including the production of cloned sprouts, the planting and management of commercial forests, Green Pig Iron®, products made of AMARU® wood, and the development of carbon projects. Based on its own experience, the company created Plantar Carbon Ltda., a company that offers services such as consultancy in the design and implementation of climate strategies and projects and carbon finance businesses mostly related to forestry activities and the sustainable use of biomass. Within the EU-funded BENWOOD project, Plantar provided information and analyses regarding the use of solid biofuels in CDM countries and general techno-economic data on the establishment and use of plantations. The main contribution was to the output 'CDM Specifics'.

:: 1.10 UNIVERSITY OF NATURAL RESOURCES AND LIFE SCIENCES, DEPARTMENT OF APPLIED PLANT SCIENCES AND PLANT BIOTECHNOLOGY, INSTITUTE OF AGRONOMY AND PLANT BREEDING (AUSTRIA)

Founded in 1872, the University of Natural Resources and Life Sciences (BOKU) is based in Vienna and currently comprises 15 departments and four service centres, as well as a number of experimental centres around Vienna. The university is attended by approximately 10,000 students, provides study courses at bachelor, master and doctoral levels and has approximately 1,800 staff and 460 persons working in services and administration. The department´s area of research and teaching covers a wide range of topics from basic molecular biology, cell biology, plant biotechnology and applied plant sciences. The aim is to form an ambitious and integrative research profile and to offer high level teaching in plant sciences. Within the EU-funded BENWOOD project, BOKU's main responsibilities were in providing research expertise on the interactions of Short Rotation Coppice (SRC) with other ecosystems.

:: 1.11 UNIVERSITY OF GÖTTINGEN, FACULTY OF AGRICULTURAL SCIENCES, DEPARTMENT OF CROP SCIENCES, SECTION AGRICULTURAL ENGINEERING (GERMANY)

Founded in 1737, the Georg-August-Universität of Göttingen is a research university of international renown with a strong focus on research-led teaching. The section Agricultural Engineering is connected to the Department of Crop Sciences and has a long term goal of finding ways to provide biomass for energetic purposes sustainably without affecting food security. One option seems to be lignocellulosic biomass, such as wood from SRF. Hence SRF and associated production systems is one major research area since the early 1990s. The university now has extensive experience in the field of SRF harvesting techniques. Within the EU-funded BENWOOD project, the University of Göttingen was work package leader of 'Dissemination', task manager of 'Overview on actors SRF and CDM/JI' and also worked on the task 'Research requirements to planting, cultivation and harvesting technique incl. logistics'.

:: 1.12 UNIVERSITY OF ZAGREB, FACULTY OF FORESTRY (CROATIA)

The Faculty of Forestry was established in 1898, when a Forestry Academy was founded within the University of Zagreb. The pride, the evidence and the organized nature of the profession is seen in the management of forests. The Faculty of Forestry is the only scientific-educational institution of its kind in Croatia and has applied the European Credit Transfer System (ECTS) which will enable students to pursue their studies at other European universities. Beside regular student education the Faculty provides knowledge in the field of training forest managers and experts on park and green area management, nursery production, environmental protection, spatial planning, clone forestry, and biomass production from forestry. Within the EU-funded BENWOOD project, the University of Zagreb (Faculty of Forestry) was work package leader of 'Linking' and task manager of 'Workshops and linking to other events'.

:: 1.13 WENA, KOCHANSKA-DUBAS JOLANTA (POLAND)

The 'WENA, Kochańska-Dubas Jolanta' company, founded in 1993, offers the production and wholesale distribution of SRF cuttings and has developed its own willow clones. About 30 varieties of willows, including 16 to 18 varieties of so-called 'energy willows' (fast growing clones) are cultivated in an area of approximately 130 hectares. The company gained expert knowledge through various research studies in field of planting systems including fertilization and nutrition. Further research and joint projects were undertaken in the field of SRF harvesting and processing systems. Besides intense activities at the national market, relevant exporting activities to former eastern countries such as Ukraine and Lithuania are present and maintained. Within the EU-funded BENWOOD project, the company was managing the task 'Profitability of Short Rotation Forestry from the Farmer's Perspective' and contributed a case study focusing on SRF tree species in Poland. Abundant knowledge contributed to the CDM project cycle.

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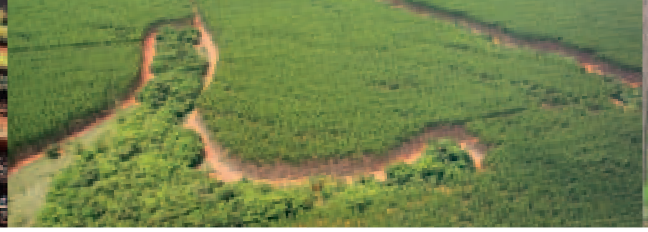

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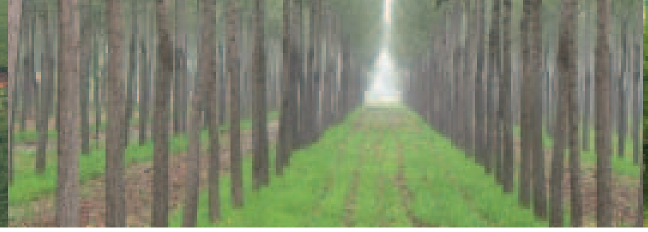

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2. Public Deliverables

:: 2.1 BEST PRACTICES OF SHORT ROTATION FORESTRY

The 'Best Practices' document describes different key aspects within the production cycle of SRF according to the 'common structure' of the BENWOOD project (Table 1). The practices are listed in an index at the end of the document. The document includes photographs for illustrative purposes, many provided by the BENWOOD project partners. Key chapters are 'harvesting' (from manual to fully mechanized options) and 'planting'.

:: 2.2 GUIDELINES ON SHORT ROTATION FORESTRY

The 'SRF Guidelines' report establishes guidelines for SRF practices to inform a wide range of potential stakeholders: farmers, project developers, investors and intermediaries. The focus of this report is on CDM countries but experiences from EU countries regarding SRF are also discussed. The SRF Guidelines is a pivotal report containing not only management issues but also other essential results from other BENWOOD deliverables. The document brings together key results for the benefit of the stakeholders mentioned above.

The report starts with a short description of the Kyoto Protocol and its financial mechanisms focusing on CDM. This is followed by information concerning A/R and SRF projects under CDM and identification of knowledge gaps which may be filled based on the output of these guidelines. Furthermore, important aspects that should be taken into account before establishing a SRF project are analyzed; recognizing cases where SRF and A/R projects can have adverse as well as beneficial impacts. SRF management guidelines are then presented and suggestions for sustainable management concerning each step of an SRF project are proposed. The economical sustainability of an SRF project is presented in the next part, containing calculations of the economic performance for different areas where SRF projects may be established. Finally, the report provides examples and case studies for planning and developing SRF projects.

:: 2.3 LAND USE MANAGEMENT STANDARDS

The 'Land Use Management Standards' report focuses on the ethical issues that may occur during implementation of SRF plantations and the potential for ameliorating any negative impacts on surrounding environment and communities. The aim of the report is to showcase case studies that have had beneficial and/or negative impacts and to show where project developers can learn from previous mistakes to ensure sustainability of their own projects by reducing negative impacts on local ecosystems and local peoples.

:: 2.4 PROFITABILITY OF SHORT ROTATION FORESTRY FROM THE FARMER'S PERSPECTIVE

The profitability analysis provides relevant case studies from four partner countries (namely India, China, Kenya and Poland). The case studies include hard data such as wood prices and according revenues, cost data for various processes (ploughing, harvesting, etc.) and in the Indian case explains more about the context of agroforestry – which is the main mean of SRF production in India.

:: 2.5 RESEARCH AGENDA ON SHORT ROTATION FORESTRY

The 'Research Agenda' gives an overview of the research areas identified by BENWOOD project partners as requiring further development. The output differentiates between **1) background** information leading towards **2) research questions** and related **3) references**. Similar or identical research questions from different project countries have been labeled. Results of basic literature research and additional information sources provided by the project partners, as well as research questions discussed at the final BENWOOD conference in June 2011, were added where appropriate (e.g. regarding CDM and climate change adaptation). The report was divided into the 16 different BENWOOD project topics, with two additional chapters containing an introduction and report analysis, and research questions regarding CDM and climate change adaptation.

Table 1: Research Agenda divided into 16 different BENWOOD topics and additional chapters.

INTRODUCTION AND ANALYSIS	CDM AND CLIMATE CHANGE ADAPTATION
Choosing the site	Preparing the soil
Genetic material	Plant selection
Planting	Cultivation and maintenance
Water management	Nutrients and soil
Risks	Interaction with other ecosystems
Harvesting	Transport and storage
Utilization of the wood	Recirculation to cropland
Agroforestry	Economics and financial issues

On average, eight research questions or specifications were identified per topic for future projects. Due to research focus and contribution of the different project partners, the research questions are either very focused in a similar vein (e.g. see 'transport and storage' mainly focusing on energy efficiency and supply chain), or they are very broad in their coverage due to the different contexts the partner countries face (e.g. 'interactions with other ecosystems'). Overall, the research questions posed by the project partners are a valuable resource for further research.

:: 2.6 WEBSITE

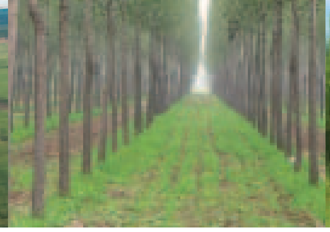
The website, besides the possibility for download of the project deliverables and a short description of the project with details of the project partners, it also provides extra materials relating to SRF and agroforestry:

+ Photographs
+ Film clips
+ Potential topics for doctoral theses
+ Useful links relating to SRF and agroforestry

The website will be the main means to continue the dissemination work of BENWOOD on a voluntary basis under the SREN network which is operated under the umbrella of the FAO.

Figure 1: Sprouting – a new cycle of SRF begins. Source: Martin Hofmann, 2007.





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3. Aspects in Short Rotation Forestry and Agroforestry

Agroforestry is understood as one of the oldest land use practices. It combines components of agricultural and forestry production within the same area of land for beneficial interactions and outcomes for both the agro-ecosystem and the farmer. Agroforestry combines the conscious production of diverse but essential resources for local subsistence. Due to industrialization and globalization, production processes have tended to become increasingly intensified and highly specialized. Agroforestry as it is traditionally practiced is unable to keep up with higher economic and mono-cultural oriented production (Sanchez, 1995). But nowadays as mitigation process towards global change, biodiversity loss, energy autarchy and changing appreciation of ecosystem functions, agroforestry and SRF emerges as a popular option to consider when faced with land degradation and the need to be productive in a more sustainable manner. Production aims ultimately change management approaches and this is in evidence when we look at the increased focus on conservation and biofuel production that is now being placed on farming and forestry systems.

The BENWOOD project aims to explore these changes in order to be able to address the resulting challenges of optimizing efficient woody biomass production on agricultural sites and whether SRF should be grown on its own or can be as part of an agroforestry system (i.e. integrated with crops and/or livestock). If the production of biomass is intensified, current production systems will need to incorporate SRF practices in a sensitive manner; specific approaches to this are already wide spread across many industrialized countries. For clarification purposes, detailed definitions of the terms used by the project to describe production systems are given below:

AGROFORESTRY

Agroforestry can be defined as a production system using agricultural and forestry techniques in close combination (Rigueiro-Rodriguez, 2009). It indicates conscious production of biological resources to meet the highly diverse demands of human subsistence within a limited production area. Especially relevant in the tropics, agroforestry practices have been shown to help improve soil qualities and therefore food and nutrition security for small-scale farmers (Nair, 2011). Recent classification of agroforestry systems mainly refer to the 1) predominant land use, 2) specific components, 3) socio-economic or cultural backgrounds, 4) ecological functions, 5) geographical and, according to this, agricultural or forestry zoning and 6) their spatio-temporal distribution and growing sequence (Nair, 1985; Sinclair, 1999; Johnson, 2006; Beetz, 2011).

Agroforestry is usually not seen as an intensive or highly optimized production concept. However, its importance and strength is located within its diverse usability in long term production systems and comparatively sustainable impacts on environment and ecosystem functions. Agroforestry systems can be very complex which should be adjusted via scientific and local experience and knowledge according to specific site conditions (Isaac *et al.*, 2008). Understanding the biophysical issues related to productivity, water-resource sharing, soil fertility and plant interactions in multiple cropping systems are essential for the success of such systems. Furthermore, if an agroforestry system is very focused in its aims of production, an optimizing process by taking into account the specific site conditions can be applicable. Although agroforestry has been considered as a panacea for maladies of intensive agriculture, benefits can only be expected when there is evidence of complementarities of resource capture by the integrated trees and crops.

A study by Price (1995) indicated a number of specific situations where agroforestry systems give greater economic benefits than either a sole crop or a sole tree system. Agricultural lands are believed to be a major potential carbon sink in the event that trees can be incorporated and judiciously managed together with crops and/or livestock (Schroeder, 1994; Albrecht and Kandji, 2003; Kumar, 2006). The strengths, weaknesses, opportunities and threats in agroforestry have been analysed by Srinidhi *et al.* (2007), and the paper highlights a need for multidisciplinary research on biophysical as well as related socio-economic aspects. Examples may be given as SRF for biomass production or focusing on service functions in relation to global climate change mitigation (World Agroforestry Centre, 2009a; Jose, 2009).

Figure 2: Production of chicken eggs in poplar plantations in China. Source: Davorin Kajba, 2008.

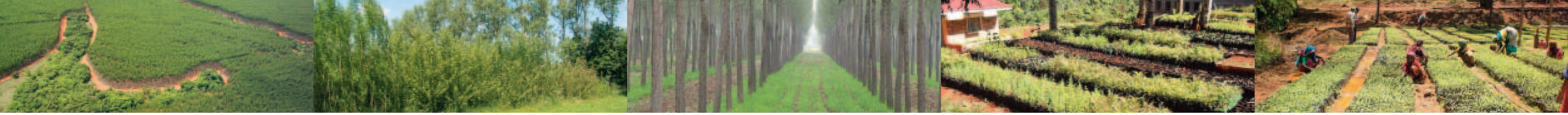
SHORT ROTATION FORESTRY

Short Rotation Forestry is a forestry practice with the primary aim of dendromass production, particularly for energy purposes, with the basic principle of growing fast-growing, deciduous tree species on forest or agricultural land at a denser spacing and higher levels of maintenance (e.g. weed control, irrigation) compared to traditional forestry. The biomass is harvested when the trees have reached a size that is easily handled and economically sound, typically between 2 and 25 years of growth. It is a system for optimum utilization of natural resources using biological, physical, theoretical and practical knowledge in an ecologically acceptable manner. The size at harvest depends on plant material, growth conditions, culture technology and desired end-product and is frequently between 10 and 20 cm diameter at breast height. SRF may be regarded as forestry or agricultural practice depending on whether a plantation is grown on forest or agricultural land. However, a sharp distinction between forestry and SRF is often impossible.

SHORT ROTATION COPPICE

Short Rotation Coppice (SRC) is an intensive SRF practice using fast-growing tree species that are able to be coppiced successfully, i.e. harvesting takes place using a process whereby the stump is left and new shoots can emerge from the rootstocks or stools. Harvests are performed in short intervals (2 to 6 years) depending on plant material, growth conditions and management practices. Planting, maintenance and harvesting is predominantly done by established agricultural practices allowing farmers to use methods and machines already known from annual cropping. According to this definition, SRC falls within SRF and simply represents a more specialized practice of SRF. As SRC is regarded as a specialized form of SRF more specifically to meet energy requirements, it will be considered in the assessments performed within BENWOOD.

The abovementioned definitions will help the reader understand the following chapters to a greater degree. The information contained in the following chapters regarding represented CDM countries (India, China, Brazil and Kenya) is based on the BENWOOD deliverable 'CDM specifics' and the information given for European countries is based on the BENWOOD deliverable 'Best Practices'.



EUROPE

KENYA

3.1 Choosing the Site

EUROPE

Successful afforestation of farmland depends on the site chosen and the conditions it poses. Whether a site can be classified as either favourable or unfavourable regarding afforestation depends on various factors. On the one hand there are natural resource factors like the supply of nutrients and water, the soil acidity and climatic factors and on the other hand there are technical issues like the slope, the total size of the area and/or logistic conditions and requirements. Furthermore, specific national regulations and laws have to be taken into account before and during afforestation processes as these may vary considerably across regions and countries.

In general, permission to afforest an area will involve assessing the size of the proposed area, a risk assessment regarding possible damage caused by the trees and certain fiscal arrangements like duties, taxes and settlement duties. Afforestation permission is a condition for granting financial incentives. In Europe it is important to make sure you have all the latest information about special restrictions and regulations for afforestation.

When evaluating a potential afforestation area, the following points need to be assessed:

+ Soil characteristics (water availability and nutrient supply)
+ Topography (mechanical access, effect on water supply and richness in minerals)
+ Exposition
+ Climate (precipitation, season temperature, humidity)
+ Area size
+ Adequate plant species adaption
+ Market demand and distances for processing or end use (optimal logistic chain)

Most of the agricultural sites, including set-asides, provide suitable growing conditions for SRF (Figure 3).

A high groundwater table has a positive effect on the growth of the trees. Liebhard (2007) states that groundwater availability from about 0.6 m to 1.5 m and a rooting depth greater than 40 cm provides an independency from precipitation and is therefore especially suitable for SRF.

Good growth rates of willows and poplars can be observed on arid to humid sites, but this is not the case on humid sites containing stagnant water; in such conditions, SRF plantation is not recommended. Dry areas that experience less than 300 mm of precipitation during the vegetation period (May to September) are also unfavourable for SRF. The average temperature of the year should not drop below 7.5 °C. Furthermore, the influence of the topographic relief must be considered. On plateaus, water and mineral supply depends on the basic rock. On top of a slope the soil is usually dry and poor regarding its mineral content whereas at the lower end of a slope the soil tends to be moist and rich in minerals. A plantation site located in a valley is permanently supplied with water which enriches the soil with important nutrients. However, late frosts can be a danger for new plant sprouts (Van Lerberghe and Balleux, 2001).

Regarding an appropriate growth of the trees, pH should be between 5.5 and 7.5; if the pH is under 5.5 the soil will be too acidic and too alkaline if above 7.5.

For the technical requirements of a SRF plantation the slope should not be greater than 15%. Although modern machinery can be used on 30% slopes, it starts to become much less cost efficient. A suitable plantation area should not be smaller than 2 ha in order to optimize the costs and should have a direct connection to roads to enable an effective transport process for the cuttings (RWA, 2007).

Figure 3: Choosing a suitable site for SRC.
Source: Daniel Amthauer Gallardo, 2011.

KENYA

In Kenya, site selection starts with a superior classification of the site into:

+ Grassland (a site with bushes but dominated by grasses)
+ Waterlogged sites
+ Bushland (dominated by shrubs and bushes)
+ Forest land (site under natural forest or previously under a plantation)

A widely used qualitative physical land evaluation method based on expert knowledge is the land suitability method developed by FAO (1976) for assessing suitability of land for a specific use. Suitability is expressed in descriptive terms: highly suitable (S1), moderately suitable (S2), marginally suitable (S3), unsuitable with (N1) or without (N2) possibilities for land improvement (Wandahwa and van Ranst, 1996).

The main criteria for site selection are:

+ Temperature
+ Rainfall
+ Soil depth
+ Depth of water table
+ Prevailing soil types – soil rooting conditions, fertility, salinity and alkalinity hazard, erosion hazards, moisture
+ Altitude

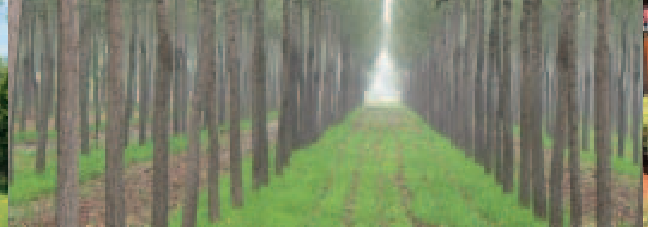
The country is divided into ecological zones that are mainly influenced by the annual precipitation and temperatures, thus resulting in six agro-ecological zones. These zones are dominated by specific tree species that are adapted to the natural conditions. The use of certain trees depends on the characteristics of the plantation site within the agro-ecological zone (Table 2).

When tree species are planted in an appropriate site to which they are well adapted, establishment and survival rate are high. But even if a chosen tree species is well adapted to the agro-ecological zone, some sites are far from being ideal for SRF. For such problem sites, there are a variety of measures that can be taken to improve their ability to support SRF. In **steep sites**, the ground is not opened during land preparation for planting to avoid causing soil erosion; planting pits are normally dug along the contour, and tree seedlings are managed through spot weeding. In **waterlogged sites**, trenches are dug to drain the water and carefully chosen tree species seedlings that can withstand waterlogged conditions are planted on ridges. In **semi-arid/arid sites**, species selection is the most critical factor and water harvesting micro structures are constructed based on the amount of rainfall received, soil type and the slope; seedlings are individually watered using bottles (bottles are covered against direct sunshine to avoid raising the water temperatures thus scorching the fine roots). **Unproductive sites** are normally not planted and are left to regenerate naturally.

Table 2: SRF tree species and associated suitable site types in Kenya.

TREE SPECIES	RAINFALL REGIME	SOIL TYPE	ALTITUDE
Cupressus lusitanica	High rainfall	Deep loamy soils	High altitudes
Pinus patula	High rainfall	Deep soils	High altitudes
Casuarina equisetifolia	Moderate rainfall	Sandy soil	High temperatures | Low altitudes
Leucaena leucocephala	High rainfall	Deep loamy-sandy soils	Low to high altitudes
Calliandra calothyrus	High rainfall	Deep loamy soils	High altitudes
Melia volkensii	Low to moderate rainfall	Sandy soils	High temperatures | Low to medium altitudes
Gmelina arborea	Moderate rainfall	Sandy soils	High temperatures | Low altitudes





INDIA

Most land in India is used for agriculture, pastures and forestry. On the basis of capability or limitations, lands are broadly grouped into two major groups: (1) land suitable for cultivation and (2) land not suitable for cultivation. The U.S. Soil Conservation Service groups lands into eight capability classes and the same is followed in India. The first four classes (I–IV) are used for cultivation whereas the remaining classes (V–VIII) are classified as unsuitable for cultivation, grazing, woodland or wildlife. The most dominant factors affecting the site types are climatic as well as edaphic, physiographic and biotic factors. However, site selection for a SRF plantation is performed based on particular site specifications, which are mainly evaluated based on the following:

+ Suitability of species for particular site
+ Soil analysis
+ Topographic aspects
+ Research backup specifically on exotic fast growing trees
+ Market demand
+ Compatibility with inter-cultivated crops

Species which benefit most from local conditions will be chosen in order to ensure a productive SRF system. Local conditions tend to influence decision-making regarding species composition, density structure and will also influence growth rate. Each and every species has its niche area and perform best under favourable local conditions. For example species like *Eucalyptus* has wider adoptability, whereas *Populus spp.* is suitable just for a limited area (north-western states with sandy loam soils, as shown in Table 3). Furthermore, local conditions of a particular area will influence the diversity and survival of undergrowth vegetation, depending on light availability, temperature, organic matter, water table, etc.

Generally the soil of a suitable SRF site should be well drained, consist mainly of sandy loam to loam, should be rich in nutrient and humus, slightly acidic to neutral and free from injurious salts and/or chemicals. Depending on altitude, the intensity and duration of solar radiation should be taken into account when selecting sites. Northern areas should be preferred but towards the upper limit of the altitudinal zone of the species, southern aspect is better at lower elevations.

If a chosen site unavoidably has some problematic conditions, there measures which can be applied for amelioration purposes. In **salt affected soils**, treatment with gypsum or something similar is an essential prerequisite for the reclamation of these soils. The physical condition of the soil should be good permeability and easy leaching. Leaching of salts and lowering of ground water table is enough to reclaim these soils. The hard layer of calcium/magnesium carbonate has to be broken physically to enhance survival rate and growth and planting technology to revegetate the salt affected soils to be standardized (pit and hole for planting) and followed extensively. *Terminalia arjuna, Prosopis juliflora, Acacia auriculiformis, Salvadora spp., Tamarix spp., Casuarina spp. and Eucalyptus spp.* can be raised to reclaim salt affected soils. **Acidic soils** can be reclaimed through lime application. On **water-logged sites**, drainage and an outlet for the excess water either from the surface or sub-surface is necessary. *Eucalyptus*, *Terminalia*, *Grevillea* and *Salix* adapt well in areas prone to water-logging. In the case of sites **characterized by sand dunes**, protection against biotic interference can be performed by treating the affected dunes via the fixation of micro wind-breaks or large scale planting of suitable tree species.

Table 3: SRF tree species and associated suitable soil types in India.

SPECIES	SOIL SITES
Populus deltoides	Sandy to fine loam, pH ranging from 6.5–8.0
Leucaena leucocephala	Variable soils
Melia composita	Sandy loam and deep fertile soils
Eucalyptus hybrid	Sandy loam, tarai and alluvial soils are suitable for a higher production. However, eucalyptus is grown almost in all the four corners of the country with variable site conditions.
Robinia pseudoacacia	Normally acidic soils and sloping lands
Morus alba	Sandy loam to clay loam
Prosopis juliflora	Saline flats, shifting sand dunes and waste/degraded lands
Gmelina arborea	Deep and sandy loam soil
Ailanthus excelsa	Porous sandy loam
Casuarinas equisetifolia	Red gravelly loam, coastal areas, saline soils
Terminalia arjuna	Moist places with sandy loam soils
Tectona grandis	Deep black soil, black clay and black loamy soils

CHINA

In China, site classification is based on three different methods. The first type is used for classifying a site according to its suitability for purpose. The 'American classification map of potential capability of eight grade land' is the representative method used for this classification. This method can be seen as a qualifying test for regional site conditions and their potential.

The second method is used for classifying forest sites. In this case, certain indices (site index, site class differences) are calculated in order to evaluate and classify sites. This type of method is visualized, but it is only suitable for a site classification of forest land and it cannot be used for non-forest land.
The third method is used for classifying sites according to four methods and their related factors:

+ Vegetation factors
+ Life factors
+ Environmental factors
+ Multiple-factor comprehensive method

With the development of numerical classification, the site classification methods used in China has changed from qualitative classification (terrain-soil factors) methods to various quantitative site classification methods.

The main factors influencing classification of site types include:

+ Altitude
+ Terrain
+ Average annual precipitation
+ Nutrient content
+ pH of soil
+ Vegetation type
+ Groundwater level
+ Lighting conditions

The success of a SRF plantation heavily depends on a proper combination of suitable tree species that match well with site conditions. However, site conditions do not only influence plantation productivity but also the vegetation growing underneath the trees. For that, the main influencing site factors are altitude, gradient and direction and position of a slope.

When tree species are chosen carefully and appropriately to match with a selected site, SRF should be productively beneficial. However, there are also certain measures which may improve site conditions in order to increase productivity or to offer the possibility to plant other tree species that may not otherwise be suitable for the site. An example can be given of planting *Populus spp.* on a site that is in a costal area with high potential for flooding stress. Favourable groundwater level for planting *Populus spp.* artificially is 0.9 to 2.4 m and therefore drainage is needed when groundwater level is under 0.6 m. In this case, drainage measures would need to be undertaken to make the site feasible for planting *Populus spp.*

BRAZIL

In Brazil, site classification methods involve statistical growth and production models. By using these models, a specific genetic material can be given its maximum productive potential for each site, taking into account factors such as soil type, annual rainfall and temperature. Therefore, sites are able to be matched with genetic materials that will offer higher productivity.

The most dominating factors influencing classification of sites are:

+ Soil type including all physical and chemical features
+ Terrain inclination
+ Altitude
+ Annual average rainfall
+ Annual average temperature
+ Sunlight and wind characteristics

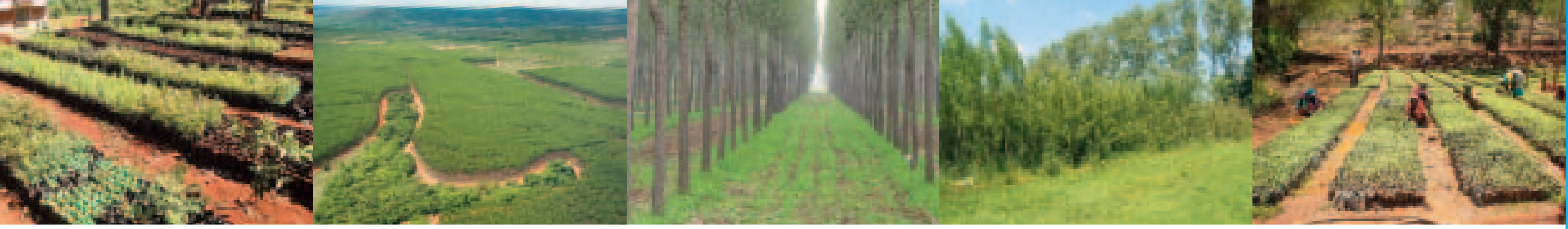
Brazil makes use of geographic information systems (GIS) during site classification for SRF. Furthermore, software such as ArcGIS and remote sensing techniques are some of the tools used for productivity classification of sites. The use of satellite images also support planning activities such as locating the best areas for forest plantations. The Space Research Institute of Brazil (INPE), a governmental agency, offers an online image database generated from Brazilian satellites which is free of charge.

The soil classification, fertility analysis, environmental indicators such as rainfall, average temperature and sunlight among others, are used in the construction of forest growth and production methods. Larger forestry companies are running forecast stations in situ, soil analysis labs and use advanced field equipment in order to evaluate the influence of environmental factors on plantation productivity.

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. How to set up proper assessment of various site factors for improved productivity of SRF species, especially regarding optimal soil and water usage?
2. Best species adaptation, precultivation of broader range of tree species.
3. Economic site optimization and market accessibility.



3.2 Preparing the Soil

EUROPE

Regarding soil preparation one may distinguish between the preparation of former **cropland** and **grassland**.

CROPLAND

Before planting on cropland the soil has to be prepared (Figure 4). Soil preparation should be a practice undertaken for effective weed control to ensure good biomass growth. Heavy vegetation should be cut and removed; initial clearing can be carried out by manual cutting, slashing, mechanical treatment (bulldozers or mulchers) and herbicide application before ploughing. Another important practice is cleaning the field of stones to allow unobstructed use of mechanical planting equipment. In the case of sloped sites, site and soil preparation should focus on techniques that prevent soil erosion and nutrient losses (e.g. artificial strip reclamation).

Different methods of soil preparation (descriptions follow on next page):

+ Subsoil ploughing
+ Ploughing
+ Heavy cultivation
+ Intermediate crops

Before applying one of the named methods there are some important points to take into account (Guidelines, 2011):

+ To avoid soil compaction, heavy equipment should not be used during rainy season
+ In order to avoid soil erosion and nutrient losses, slopes greater than 15% should not be ploughed mechanically
+ If operations can only be done manually (soil preparation with hoes, forks, spades, etc.) digging to a maximum of 15 cm is recommended

:: SUBSOIL PLOUGHING

One aim of subsoil ploughing is to increase the volume of soil and, furthermore, the process ensures that any obstacles are destroyed mechanically before planting. Subsoil ploughing penetrates problematic soils like clay and chalky tufa and loosens superficial horizons compacted by the weight of animals or machines. This leads to fewer obstructions to hamper the development of planted trees. Subsoil ploughing also encourages draining action as the horizons can absorb circulating surface water and accumulate it in suspended layers.

There are various types of equipment to perform subsoil ploughing. It is possible to choose between different types of frames (straight or v-shaped frames) and different kinds of teeth (bent towards the front, straight or curved). A 'ripper' may be used for planting long rods as it consists of only one tooth.

To find out the right timing for subsoil ploughing, first of all it should be checked which layer has to be dissolved. To plough efficiently the teeth have to be 10 cm under the layer. For hard clayey soils subsoil ploughing is not recommended. For intermediary soil subsoil ploughing is possible but difficult, and on semi-plastic soil in a wet state it is quite inefficient. If subsoil ploughing is planned on gradients, the direction of the farrows should be according to the contour line to reduce the risk of erosion.

:: PLOUGHING

There are several reasons to plough a site before planting. The soil is exposed to the natural climate, second it encourages the root system to develop, third it eliminates the grass cover and lastly it loosens the soil and protects the structure. Two kinds of equipment mainly get used for this purpose: the ploughshare plough and the disc plough.

For the right timing for ploughing it has to be checked if the present status of soil justifies the planned action. Van Lerberghe and Balleux (2001) mention that it is beneficial to turn over the soil via deep ploughing which leaves upright furrow slices than to perform heavy cultivation. The soil has to be ploughed when it is friable. The best timing for ploughing is usually either in autumn during the frosty winter months when the soil is exposed to the climate (crumbling through frost) or in spring when the grass cover is turned over.

Figure 4: Preparing the soil with machines. Source: WENA, 2010.

:: HEAVY CULTIVATION

The main objective of heavy cultivation/harrow is the preparation of the land for ploughing and to create a fine grained structure of the top soil. For sufficient root development in poplar the soil should be fluffy otherwise the root respiration may be impaired (Lewis, 2007). An increased compaction of the soil has negative effects on the success of a plantation. Therefore any kind of soil treatment should be avoided when soils are wet (Guidelines, 2011). The equipment used for heavy cultivation is the cultivator which is for shallow ploughing, for incorporating fertilizers and to carry out shallow cultivation. There are also a range of harrows fixed with teeth. Within the harrows one may distinguish between the chisel cultivator, the disc harrow and the rotary cultivator.

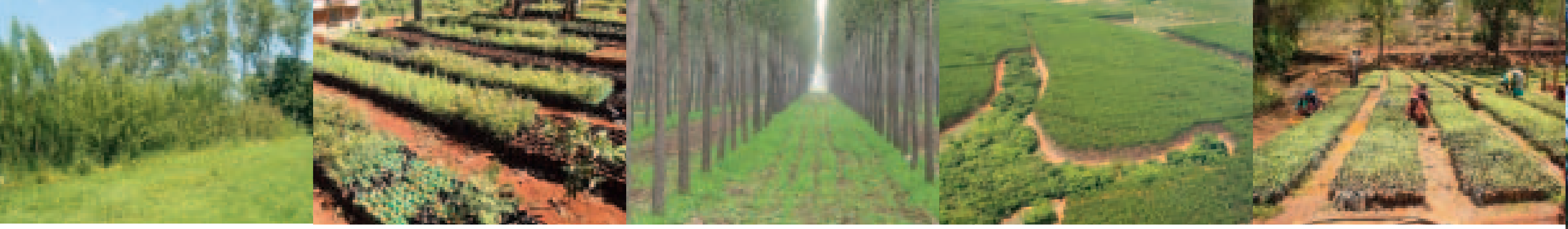
The heavy cultivation period depends on the objectives. To achieve a good reduction of germinated weeds, disk harrowing in combination with an herbicide application is recommended a couple of weeks before planting (Guidelines, 2011).

:: INTERMEDIATE CROPS

Lewis (2007) recommends intermediate cover crops in winter before planting. The aim is to stabilize the soil after ploughing so the crops should be deep-rooting. Buckwheat and mustard are crops which cover the soil and improve the soil structure, thus, fostering trees' growth. Advantages of cover crops are that they reduce the weed growth, reduce the risk of erosion in hilly areas and that they are not in competition with the trees.

GRASSLAND

When planting cuttings on grassland, the same soil preparation methods as mentioned above are suitable and recommended. In the case of preparing grassland for planting rods, a one tooth subsoil plough is required with a planting depth of 90 cm; this creates a ditch in which the rod is planted (Hofmann, 2005). However, this technique does harbour the risk that the gap dries out quickly.
If, for whatever reason, a site cannot be prepared according to the abovementioned methods it is possible to dig planting holes manually (Guidelines, 2011).



KENYA INDIA

KENYA

The preparation of the soil before planting trees depends on the characteristics and condition of the site. In general, planting sites are cleared of weeds before planting and complete cultivation of the site takes place; this is recommended for fast establishment and survival of seedlings. Bushes on-site are slashed manually and either heaped for burning or, alternatively, the bush cuttings are left on the site/between the rows as mulch.

Steep land is rarely fully exposed during land preparation as this may lead to soil erosion. Usually, just the planting strips are slashed of vegetation along the contours and cuttings heaped at the lower side of the strip. Planting pits are then dug in the middle of the cleared strips. Most of the vegetation between the cleared strips is left intact, thus, posing a major challenge in terms of competition for both nutrients and moisture. With the well established root systems of the existing vegetation, competition for nutrients sets in within a short period after planting. A site planted using this approach requires frequent maintenance to reduce shading and competition for nutrients. Complete cultivation is not allowed on such sites while maintenance of young seedlings involves spot weeding at 0.5 m radius around the seedling.

Figure 5: Forked hoe (Jembe). Source: Genevieve Lamond, 2011.

The majority of afforestation sites in Kenya, especially public land, are prepared manually due to the lack of machinery and/or the high costs for hiring tractors or other appropriate mechanical equipment (Figure 5). The farmers normally use hand held tools (hoes, forks and machetes) to prepare the site and, using these tools, soil is dug to a maximum of 15 cm. Where soil preparation has involved manual digging to too shallow a depth, root development can be impaired and the roots do not penetrate the deep soil horizon. A result of this is that a tree will spread its roots close to the surface and will have poor wind resistance, usually falling over easily. Furthermore, it would not be able to withstand drought conditions even when mature as roots would not be utilizing the deeper soil horizon that retains moisture for longer periods. Such trees are also easily attacked by pests such as termites that effectively kill them, especially during the dry season due to the trees already experiencing stress because of lack of moisture. Because of the consequences mentioned above, deeper pits are often dug specifically for planting seedlings when preparing the soil manually.

Where an individual farmer has used a tractor to plough the site, which is quite rare, the soil is dug deeper throughout the whole site. However, depending on the site condition, deep cultivation can have advantages and/or disadvantages. On good sites, a deep cultivation can have favourable effects on growth rate of seedlings as the deeper soil layers can hold more moisture and nutrients. On the other hand, if the site is poor with shallow soils underlain by a pan of murram (petroplinthite), deep cultivation can cause a higher distribution of the limited nutrients into a larger volume of soil and, therefore, become less available for the seedlings. However, deeper dug sites still hold more soil moisture than those shallowly dug. A complete cultivation of the plantation site, which is not allowed everywhere, has positive effects regarding seedling establishment and survival and growth rate, leading to higher wood yields at rotation.

Where slashing and burning is done, higher survival and growth rates are recorded especially where these measures are followed with frequent weeding of the seedlings. The burning causes quick release of plant nutrients and therefore makes them available to the planted seedlings. However, as slashing of the weeds keeps the weed stumps intact there can be competition between side vegetation and seedlings for available resources. This may lead to a depressed initial growth and, thus, poor productivity unless vegetation is suppressed regularly.

Figure 6: Soil preparation with cattles. Source: PAU, 2010.

INDIA

When preparing the soil for plantations in India, the main focus is on the weeds. Weeds have an invasive nature and newly raised plants need some time to establish. If not controlled, weeds may overtake the raised plants, thus, affecting their survival as well as growth due to competition for light, nutrition and moisture. Weeds in plantations are controlled through a variety of manual, mechanical, chemical and biological methods.

In general, weed control in plantations mainly involves two operations, i.e. suppression of weeds and elimination of weeds. **Weed suppression** can be carried out by means of trampling, beating or cutting them down and most common is to cut them back using cutting tools like a sickle or axe. Close spacing is another strategy to suppress weeds because it causes the canopy to close quickly and reduces weed growth; however, for potential mechanization a wider spacing would be essential. **Weed elimination** requires removal of weeds along with roots, which requires soil working (digging/chopping, ploughing) and/or herbicide application. Foliar sprays of brush killer (2,4,5-T and 2,4-D) are effective in controlling broad-leaf weeds including *Lantana* in plantations.

Steep land is recommended to be terraced (with inward slope on contour) in order to prevent damage by heavy rains. Planting occurs on these terraces in horizontal lines commencing at the top of the slope. To protect the plantation site from erosion, due to surface water run-off after rain events, and to retain that water it is recommended to build trenches, which can vary in width. In steep areas it is common to plant hedge rows (e.g. *Leucaena spp., Gliricidia spp.*) and nitrogen fixing trees and shrubs with high density across the slope. Sloping Agricultural Land Technology (SALT) is highly developed in the hilly areas in Southeast Asian countries, including India.

Most of the land in India is cultivated manually as land holdings are too small to make mechanization cost effective (Figure 6). However, manual land cultivation supports the employment of people and is cost effective. Mechanization is reserved for big companies and farmers holding larger areas of land.

CHINA

In China, most short rotation plantations are planted on bare and/or clean soil. The soil preparation for SRF equals the modern soil preparation for agricultural sites. When choosing sites with abundant weed and shrubs or even forest land, it is necessary to clear the forest land and control the weeds. This can be seen as one key measure for a successful and productive short rotation forest.

Soil preparation often starts in autumn while afforestation is realized in the following year. In northern parts of China, herbicide is first used to control weeds. After a week, the turf is pulverized using a disc harrow which creates a 10 cm shallow tillage. Disc harrow plus an herbicide application is repeated in the following spring to prevent annual weed germination. If the planting spacing is 3.3*3.3 m or narrower, there is no need to continue removing weeds due to early canopy closure. When the planting density is low, weed control and tending is necessary after planting until canopy closure, especially when fertilization and irrigation are not being practiced.

Mechanical cultivation has good effects and cost efficiency on plain and gentle sloping lands but cannot be used on sloping lands. Only manual soil preparation is suitable on sloping lands. Manual soil preparation includes: full cultivation, strip cultivation, broad base terracing and hole-digging. According to research results, manual strip cultivation is the best type of soil preparation for a productive forest on sloping lands. This type of soil preparation was shown to reduce competition between weeds, shrubs and plantation trees effectively and is favourable for improved root development which is important in relation to tree growth rate. Furthermore, this type of soil preparation is beneficial in order to prevent soil and water erosion and nutrient losses and is cost effective. Therefore, it is used by many afforestation and production departments for steep areas.

China mainly uses three different types of soil preparation, which each have different effects on tree height, diameter at breast height and volume growth. These different methods of soil preparation are:

+ Two times mechanical reclamation
+ One time mechanical reclamation
+ Manual hole-digging

Under similar site conditions, with the same improved seed, management conditions, fertilizing proportion and amount, the mechanical reclamation soil preparation measure can promote rotation yield effectively. The yield and economic benefit of plantation sites using mechanical soil preparation is generally better than sites using manual hole-digging. From an economical point of view, out of the abovementioned soil preparation methods, the 'One time mechanical reclamation' is seen to be the most beneficial. These site preparation methods all have particular impacts on parameters like root development and wind resistance and, therefore, influence the productivity and risk vulnerability of the plantation.

In conclusion, the choice of a certain preparation technique heavily depends on (a) the available facilities and resources; (b) the specific site and area conditions and (c) on the potential plantation material.

BRAZIL

In Brazil, site preparation in general and soil preparation in particular is aimed at making water and nutrients available for fast root development and growth of the plant. Preparation techniques aim to increase water and nutrient absorption by the improvement of physical properties of the soil such as porosity and reduction of resistance imposed on root growth. Minimum tillage, which has been increasingly adopted in Brazil since the 1980s, contributes to a reduction in nutrient loss, reduction of weeds, reduction of soil disturbance, and increased microbiological activity in the soil. Weed control is usually done using manual and/or chemical procedures. The application of herbicide for clearing purposes is done prior to planting with the use of sprayers. Whenever the terrain is unable to allow spraying machines to operate, the application of herbicide is carried out by workers with specifically designed tools. Site and soil preparation is usually done manually by small scale producers due to the high costs of mechanization. In the case of forestry companies in Brazil, soil preparation is done mechanically and is the most viable method. Due to the large scale of the companies, the operational cost is much lower when mechanized. Besides that, mechanization establishes a quality pattern for the task and requires skilled labour for the activity.

Site and soil preparation on sloped lands is done by cleaning the planting lines according to the contour lines of the terrain. The line is about 1 m wide, giving the plants a 50 cm radius of weed free area. This line can be prepared manually or via the application of herbicides. This practice leads to less negative impacts on sloped lands by controlling soil erosion and degradation, and slowing down rain water on the surface which also reduces erosion and loss of fertilizers and herbicides.

Subsoil ploughing is widely used as a means of mechanized preparation of the soil, and is used for minimum tillage and total area preparation. The destruction of rigid soil structure in deeper areas enables improved development of tree roots. Moreover, better distribution of fertilizers such as phosphorous throughout the depth of the soil improves nutrient availability. Generally, subsoiling reaches depths between 40 and 60 cm. The soil disturbance caused by subsoil ploughing reduces soil compactness which allows for improved productivity. This method of soil preparation can be very useful for transforming areas by eliminating stumps and weeds, thus, reducing competition for soil nutrients. Minimum tillage helps the soil to maintain its physical and chemical properties (erosion control and nutrients maintenance) due to the reduced exposure of the soil to weather conditions; this is important for maintaining/increasing productivity.

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Site preparation for optimal root penetration.
2. Meteorological impacts on the soil and reducing adverse impacts on planted material (frost, temperature impacts).
3. Establishment of planting guidelines for soil preparations (e.g. best practices for avoiding exposed soils).
4. Effective soil management to avoid long term degradation.

3.3 Genetic Material

EUROPE

:: PLANTING MATERIAL ADAPTED TO LOCAL CONDITIONS

Planting material should be adapted to local conditions as much as possible, taking into account climate, solar radiation and soil qualities. It may take 8 to 10 years to reveal any lack in adaptation if the initial phase proves successful, so it is vital that planting material is matched to site conditions as far as possible to avoid a disappointing end-result. As this problem is well known in forestry, certain laws in European states prescribe long-term testing periods before provenances of trees can be used commercially for forest purposes. These obligatory rules have the disadvantage that there is a delay in bringing new clones on the markets. In Austria there are no rules for clones used in SRF.

The genome of poplar is smaller compared to other tree species which means that small changes in the genome have large effects on the characteristic of the clone. Therefore, breeding progress in poplar is high. On the one hand this is beneficial to achieve certain breeding goals (e.g. higher yielding) but on the other hand there is still a risk that other characteristics will become exaggerated to the extent of becoming detrimental (e.g. more prone to infestastions of pests and diseases).

Clones have been shown to perform differently under different environmental conditions. This can be observed impressively when the performance of willow clones in Scandinavian countries or Austria and Italy are compared. In one case study, clones from Sweden which were planted in Austria lost their leaves prematurely due to different day lengths in Austria and Sweden. Another example for the importance of choosing the right clone for the right place comes from Italy where Alasia New Clones bred a clone for cooler areas; although this clone underachieved in Italy it showed great performance in northern parts of Austria. It is vital that farmers and producers take into account site conditions when selecting planting material for their plantations.

The market demands clones with highest possible yields which means that breeders are under pressure to meet the demand. One strategy is to ensure new clones have their ancestral source originating from similar geographical latitude as the planned planting area.

:: COPPICING

The development of main and side shoots depends on two facts: the tree genus and the clone.

Most poplar clones grow only one main shoot in their first rotation. In the following rotations the number of shoots will range between 1 and 2.2. However, on average, willow grows more shoots than poplar. Willow has 2.5 to 3.5 shoots per plant in the first rotation. Due to competition for light this number will somehow stagnate and reach a maximum of about 4 shoots per plant. When selecting planting material for coppicing purposes, it is important to take into consideration how well the tree will respond to regular cutting and ability for regrowth during the life of the plantation.

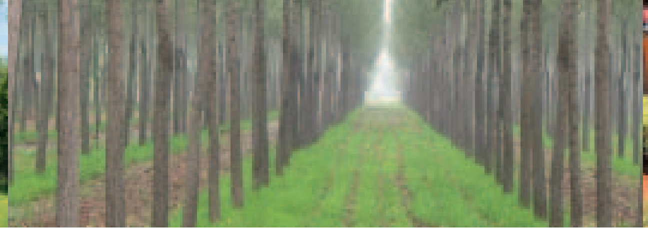
:: PREFERRED TREE SPECIES IN EUROPEAN SRF AND AGROFORESTRY SYSTEMS

In Central Europe, poplar and willow are the major tree species for commercial SRF which is focused on high yields. Experiments have shown that other species used for SRF, such as alder (*Alnus*), birch (*Betula*) and robinia (*Robinia pseudoacacia*), have significantly lower yields than poplar and willow (Hofmann, 1998). Due to climatic conditions, willow is well distributed in northern Europe, whereas poplar is preferred in southern Europe. At the moment Austria and Germany recommend planting poplar but willow should not be overseen as it shows great performances on humid soil with good water holding capacity.

Important requirements when selecting clones are:

+ Light demanding tree species
+ High tolerance against early and late frost
+ The planting material should be vegetatively reproductive at low cost
+ Stable growth in the early phase (high survival rate)
+ Competitiveness and compatibility in high density stand
+ High net assimilation
+ Long vegetation period; late leaf drop
+ Adapted to different day lengths
+ High stability and straight stem
+ Narrow compact tree with steep angle of the branches
+ High regeneration ability for many rotations
+ High tolerance to diseases, pests and game damage





WILLOW

In the U.K. most willow types used for SRC descend from *Salix viminalis* (Osier willow). For the selection of new willow genotypes the following characteristics are important: yield, rust resistance (*Melampsora epitea*) and growth form. Recently, 32 genotypes have been evaluated and after the first two years some genotypes were shown to have significantly higher yields when compared with standard genotypes (AFBI, 2007).

POPLAR

About 40 poplar species are known worldwide (Kuratorium für Technik und Bauwesen, 2006). The *Tacamahaca, Populus nigra* and *Leuce* poplars are favoured for breeding as they show high performance during initial and youth phase (Figure 7). Furthermore, they can be planted at high density. Until the year 2000 there was an increased interest in only a few poplar species like *Populus nigra, P. deltoides* and *P. trichocarpa* (American species) and their hybrids but the interest has since widened (Weisgerber, 2000). Poplar is more sensitive regarding adaptation to local conditions when compared with willow resulting in lower survival rates after planting.

BALSAM POPLAR

In Europe, balsam poplar and their respective hybrids are suitable for SRF. *P. trichocarpa* and *P. maximowiczii* are more modest than black poplar species; Hofmann (1998) states that they perform well at sites with medium nutrient input, dry soils and at high altitude. *P. trichocarpa* clones do not need high levels of light energy to perform proper photosynthesis and are therefore suitable for shady sites (Lewis, 2007).

TREMBLING POPLAR

Trembling poplar (*Populus tremula*) has the highest tolerance regarding the choice of planting site. They have satisfying yields on modestly dry to wet-dry soils as well on compacted, waterlogged soils and shallow grounds with a medium water and nutrient supply. However, for a commercially viable SRF plantation they need fresh, nutrient-rich clayey sands (Hofmann, 1998; Traupmann *et al.*, 2004). A disadvantage is that they have the tendency to produce basal shoots which has negative consequences for harvesting after the first rotation. Furthermore, trembling poplar cannot be planted as cuttings under outdoor conditions. Vegetative reproduction is available via plant tissue culture techniques.

BLACK POPLAR

Black poplar is relatively demanding regarding optimal light, temperature and water conditions. They need well aerated and nutrient enriched soils which can be easily penetrated by the roots. Black poplar does not perform well on waterlogged sites or against crown competition. Although black poplar is usually not used for SRF, they are valuable as a genetic resource in breeding schemes (Hofmann, 1998).

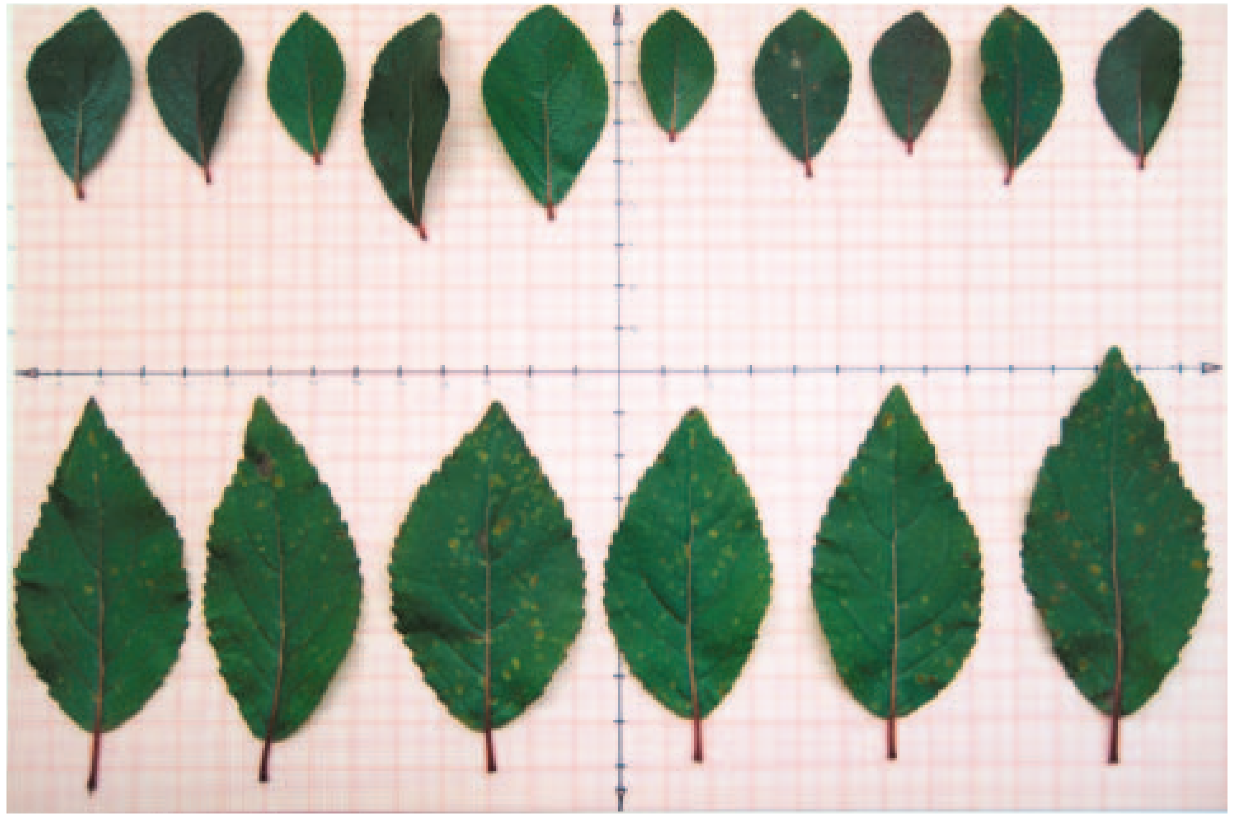


Figure 7: Selection. Source: Nordwestdeutsche Forstliche Versuchsanstalt, 2010.

KENYA

Clone breeding with regards to trees is relatively new in Kenya and is mainly at research stage except for some eucalyptus hybrid clones brought in from South Africa. These clones are currently being raised locally in two places in Kenya: at the coast (Malindi) and centrally (Nairobi). While some research activities on appropriate sites for establishing the majority of these clones have been carried out, some of the earlier plantings were rather poorly sited and therefore experienced poor growth. The driving motivation for planting the clones was displaced as most farmers expected to sell their eucalyptus trees for electricity transmission poles at a premium price but the trees' strength proved inadequate. The same material is grown for pulp production in South Africa. The current varying growth of clones in the field shows that proper research on clone-site matching should be carried out prior to expansive planting. In South Africa the planting of clones has been taken up by private companies targeting specific products whereas in Kenya small scale farmers are the main consumers of the clones and these farmers often have diverse expectations that may not be realized.

The current stage on clone breeding research is at the selection of superior trees of various species which include:

+ *Cupressus lusitanica*
+ *Pinus patula*
+ *Melia volkensii*
+ *Osyris lanceolata*
+ *Vitex keniensis*
+ *Eucalyptus grandis*
+ *Gmelina arborea*
+ *Ocotea usambarensis*
+ *Grevillea robusta*
+ *Eucalyptus nitens*
+ *Eucalyptus saligna*
+ *Pinus caribaea*
+ *Pinus tecumininii*
+ *Pinus maximinoi*
+ *Eucalyptus urophylla*
+ *Eucalyptus camaldulensis*
+ *Eucalyptus tereticornis*

Besides selection of superior individual trees from natural and planted populations, the other main research area has been on determining the appropriate conditions for rooting cuttings and necessary treatments, if any, that could be used for commercial production of planting material.

The common method of propagation is through rooting of cuttings. This involves the establishment of hedge rows of the different clones where they are maintained under vigorous growth and encouraged to develop into a hedge without growing in height. The young shoot tips are harvested regularly and rooted under non-mist propagators from where, once they are established, they are hardened before transplanting into the field. So far this has been achieved for the eucalyptus hybrid clones.

A critical development is that some of the above mentioned species have been heavily exploited in their natural populations and, thus, selection is being carried out based on already degraded populations. Once farmers establish some of these clones, there has been a tendency for people to collect seed from such populations with the hope of creating a F1-generation which performs at parental level. There are currently no regulations guarding against this practice.

Due to the highly variable agro-ecological zones in Kenya, clones have to be very well matched to regional conditions. Therefore, selection of genetic material should be based on the appropriateness for specific regions and conditions. In humid areas with high rainfall the most important performance parameters are growth rate and yield. In contrast, when selecting plants for dry areas several factors are considered including drought tolerance, growth rate, pest tolerance and yield.

The following species are particularly suitable for dry areas:

+ *Melia volkensii*
+ *Osyris lanceolata*
+ *Eucalyptus camaldulensis*
+ *Eucalyptus tereticornis*

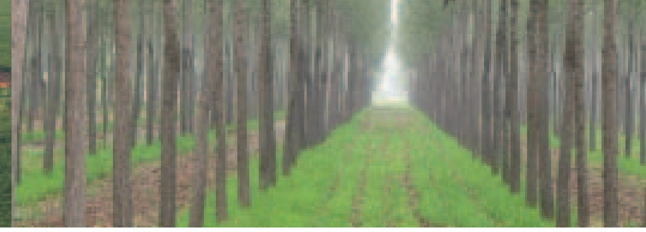
These species are not being used commercially for establishment of plantations. Currently, tree planting in the dry areas is still not a major activity and is mostly carried out at a very small scale. *Melia volkensii* has been planted by some farmers especially around research stations where research trials have been established. *Melia volkensii* and *Osyris lanceolata* seedlings are usually collected by farmers as wildings whereas the exotic eucalyptus species are bought from local nurseries.

There is also the possibility to import clones from abroad. Clone material to be imported or exported needs to be cleared by Kenya Plant Health Inspectorate Services (KEPHIS). This involves getting an import permit which has to be sent to the respective export country as well. The exporting country has to send the material according to the regulations and restrictions of the import country. These regulations are very strict to avoid potential infiltrations of pests and diseases.

Ministerial pronouncements against certain tree species, such as *Eucalyptus spp.* have caused at times the cutting and uprooting of trees on farms. However, reforestation and afforestation achieved through clonal imports will potentially have a major positive environmental impact, especially to the rural communities that depend heavily on firewood energy. A lot of deforestation and resultant loss of top soil due to soil erosion has occurred because of a lack of seedlings to plant to replace the trees cut for firewood.







KENYA

INDIA

BRAZIL

Clonal plantations are generally not common in Kenya. Specifically they have not yet been planted in the public forests and have only been used in private forest – this has been eucalyptus clones, after their introduction from South Africa. However, monoculture plantations of several exotic and few indigenous trees species do exist.

The transfer of proprietary improved eucalyptus germplasm from South Africa to Kenya has been done under a research agreement. Utilization of this superior germplasm for commercial forestry will require negotiations and consideration of Intellectual Property Rights (IPR). Traditionally, tree seedlings have been raised from seeds that are collected from available trees or bought at a relatively small cost. These factors can be seen as a limitation for widespread uptake of clonal plantations.

Major factors limiting interest in clonal or mono-cultural plantations are:

+ Uncertainty of risk of pest and disease outbreak
+ High intensity of management
+ Costs of raising clones

These various factors act as a deterrent for resource poor farmers who also lack the skills to carry out the propagation.

INDIA

In India, species like poplar, eucalyptus, and casuarina are extensively propagated clonally and activities at commercial level have not been extended to other species. Propagation in most other species is through seed. However, the use of certain species depends heavily on regional conditions and some species have been found to be better adapted to certain areas and their specific conditions than other areas (Table 4). Most plantations are planted as mono-clonal due to management and productivity issues; however, multi-clonal plantations are recommended and also exist as they broaden the genetic base.

When developing new clones the main requirement is high biomass production followed by adaptability to difficult site conditions and disease and insect tolerance. However, genetic testing through biotechnological approaches is costly and therefore not performed. Highly productive planting material may also be imported from abroad for plantations on suitable sites after thorough testing. Gaining permission from the National Bureau of Plant Genetic Resources (NBPGR, ICAR) is essential for importing material. The import material is released only after quarantine check regarding hygiene and biodiversity issues by NBPGR.

Table 4: The distribution of SRF tree species in India.

SPECIES	DISTRIBUTION
Acacia auriculiformis, A. mangium, A. mollissima	Humid tropical regions in north-eastern and the humid tropics in southern states
Populus deltoides	Irrigated agro-ecosystem in north-western states
Leucaena leucocephala, Eucalyptus hybrid	Distributed throughout the country
Robinia pseudoacia, Morus spp.	In temperate mid-hills of the north-western Himalayas
Prosopis juliflora	In arid and semi-arid areas
Gmelina arborea	In north-eastern humid tropics
Bamboo	Distributed throughout the country, major diversity in north-eastern states
Anthocephalus cadamba	In the north-east
Ailanthus excelsa	In central India, in the northern part of Peninsula and in some arid parts of India
Casuarina equisetifolia	Coastal areas and salt affected soils
Terminalia arjuna	Lower Himalayan tracts and Eastern India
Cryptomeria japonica	East Himalaya and humid regions

BRAZIL

According to ABRAF, 56% (2,534,240 ha) of eucalyptus planted forest areas in Brazil (by 2009) are located in the Southeast region, especially in the states of Minas Gerais (1,300,000 ha), São Paulo with 1,029,670 ha and Bahia (628,440 ha), with participation of 29%, 23% and 14% of the country, respectively. These three states together have 2/3 of the total area planted with this species in Brazil. Regarding pine, the Southern region has the largest planted forest area of this species, totaling 1,417,850 ha in 2009, representing 79% of total planted pine forest area in Brazil. The state of Paraná leads pine planted forest area, followed by Santa Catarina, with 695,790 ha and 550,850 ha, equivalent to 38% and 31% of the total, respectively.

Besides eucalyptus and pine planted forests in Brazil, which are the most representative species, other commercial tree species planted also deserve attention due to their economic importance and growth in planted areas in recent years:

Table 5: Details of other commercial tree species in Brazil.

SPECIES	SCIENTIFIC NAME	MAIN STATES WITH PLANTATIONS	AREA IN 2008 (HA)	AREA IN 2009 (HA)	MAIN USES
Wattle	*Aracia meamsii and Aracia mangium*	RS, RR	181,780	174,150	Wood: energy, charcoal, wood chips for pulp, wood panels Tannin: leather, adhesive, rubber
Rubber Tree[1]	*Hevea brasiliensis*	Amazonia	129,850	128,460	Wood: energy, pulp Sap: rubber
Paricá	*Schizolobium amazonicum*	PA, MA	80,180	85,320	Veneer, and plywood ceilings, toothpicks, paper, furniture finishes and mouldings
Teak	*Tectona grandis*	MT, AM, AC	58,810	65,240	Civil construction (doors, windows, panels, ceilings), floorings and decks, furniture, ships and decorative veneers
Paraná Pine	*Araucaria angustifolia*	PR, SC	12,520	12,110	Sawnwood, veneers, ceilings, mouldings, blat, boxes, furniture structure, matches, pencil and spools
Poplar	*Populus spp.*	PR, SC	4,020	4,030	Matches, furniture parts, doors, interior woodwork, toys, kitchenware
Others[2]	–	–	1,870	2,740	–
	TOTAL		469,030	472,050	

Source: ABRAF Members; Sao Paulo Association of RubberProducers and Manufactures (APABOR); Paricá Research Center (CPP), IBGE, various companies and sources; STCP, 2010.

[1] Rubber tree planted forest area in Brazil has been revised based on APABOR data.

[2] It includes forest areas with ipé-roxo (*Tabebuia spp.*), fava-arara, Jatobá (*Hymenaea courbaril*), mahagony (*Swieta macrophylla*), acapu (*Pericopsis elata*), among others.

CHINA

In the 1980s, the forestry economic objectives expanded on traditional objectives, emphasizing wood-based production at a sustainable level to achieve a proper timber production with regards to forest ecology, environmental and social benefits. In the 1990s, people became more aware of the potential of cloning for industrial plantations. Thereafter, the research of clone-breeding based on cuttings expanded and made major progress. At present, after years of efforts, the clones of fir, white elm, casuarina, poplar, eucalyptus and other species have reached the stage of production and utilization. Studies on clone species for pulp wood production have included research on ecological stability, adaptability and genetic variation. These basic studies also solved some technical problems of eucalyptus, acacia, fir, pine and larch breeding and have, therefore, laid the foundation of clone breeding in China.

In China, the main breeding goals are tree characteristics of high growth rates and yields. Beside this, the focus is also set on matching tree clones with site conditions of certain problematic areas, e.g. arid lands and their specific conditions. Suitable tree species for arid areas are mainly *Buckthorn, Atyiplex canescen, Pinus massoniana, Arborvitae, Staghorn sumac, Robinia, Amorpha fruticosa, Salix and Caragana*. For the restoration of land in arid areas, sand-fixing plants are mostly cultivated. Some region-specific SRF species are given in Table 6.

Compared to developed countries, China still has some deficits in high-end technology such as somatic cell embryo testing techniques for *Picea abies*, Colorado spruce and other tree species. Certain pilot studies exist regarding the topic but faster development on this would be beneficial.

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

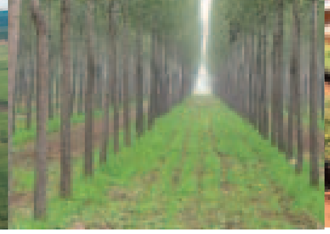
1. Introduction and testing of new suitable species/clones for specific end-uses i.e. timber, fuel, phyto-remediation, problematic soils. Field trials for comparison of old and newly introduced clones/species.
2. Collection of new germplasm of willow and poplar from natural populations; especially where environmental conditions are challenging (frost, drought prone) for increased tolerance.
3. Development of native species for SRF.
4. Clones for different zones: genetic adaptation at different potential sites.

Table 6: The distribution of SRF tree species in different regions of China.

SPECIES	SUB-SPECIES	REGION
Poplar	Chinese white poplar	Regions around the Yellow River
	Occidental poplar	North China
Eucalyptus	Urophylla U6 Hybridized, Eucalyptus LHI Hybridized, Eucalyptus East China sea No 1, Urophylla shilling No 1	South China
Paulownia	---	Nation wide
Morrisonicola	---	Nation wide
Seabuckthorn	---	Middle regions around the Yellow River

Figure 8: Examples for tree species suitable for SRF. a) eucalyptus, b) birch, c) robinia, d) willow, e) poplar. Source: Genevieve Lamond, 2011; Christian Siebert, 2009; WENA, 2009; Martin Hoffmann, 2010.





EUROPE KENYA INDIA

3.4 Planting Material

EUROPE

There are different types of planting material which can be used for SRF and the main ones used in Europe are cuttings, rods and rooted plants.

:: CUTTINGS

Cuttings are parts of forest plants (mostly twigs, branches, 'sleeping' cut-offs) without roots which are planted directly into the ground where they start to sprout and finally produce a new plant (Figure 9a). This propagation is an asexual process and cuttings are generally taken in autumn.

The diameter of cuttings should be a minimum of 1 to 2 cm. They should be undamaged and have at least 2 buds. The length of traded cuttings is about 20 cm (Figure 9b). Austrian experts recommend a length of 25 cm to provide the cutting with enough humidity (Best Practices, 2011).

To protect cuttings from desiccation, the tips can be covered with cold wax. Lewis (2007) suggests a 5 cm cold wax covering which has been shown to be beneficial regarding successful initial growth rate. Cuttings are stored cold and humid which also describes the best transport conditions. One major advantage of using cuttings is they can be planted in high density (30,000 to 35,000 plants/ha).

Figure 9a: Longer cuttings (40 cm length). Source: Forschungsinstitut für schnellwachsende Baumarten, 2003.
Figure 9b: Cuttings (20 cm length). Source: Christian Siebert, 2011.

:: RODS

The average length of rods is between 1 to 2 m. Rods are more expensive than cuttings. Their use is recommended when targeting larger stem diameters and longer rotation periods of 10 to 20 years. Rods are also suitable for replacing failed trees within a plantation. In Germany, there are usually two different types of rods; one type of rod is planted up until an age of 1 to 2 years and the other type of rod is planted at an age of 2 to 4 years. The first type is usually about 100 to 250 cm in length with a stem diameter between 1 and 3 cm, and is recommended to be planted at 30 to 50 cm depth into the soil (Figure 10). The second type of rod is usually 200 to 400 cm long with a stem diameter between 2.5 to 5.0 cm, and the recommended planting depth is 70 to 100 cm. Quality parameters for healthy rods are a straight growth and an undamaged bark (FNR, 2010).

In general, rods are mainly used in SRF for stem wood purposes. Planting density is therefore 500 to 1,000 plants per ha. Once established, a plantation does not need any maintenance management due to the height required.

Figure 10: Rods (150-200 cm length). Source: Marco Lange, 2010.

Figure 11: Eucalyptus seedlings. Source: Genevieve Lamond, 2011.

:: ROOTED PLANTS

There are two kinds of rooted plants, the 'normal' bare rooted plants and the containerized plants.

To produce bare rooted plants the seeds are sown in nurseries where they grow for one or two years. Afterwards, they are planted to a bigger area in order to give them the opportunity to develop properly. This period can last up to two years before being ready for transplanting to the field.

Containerized plants are cultivated in plastic containers in greenhouses which allows for conditions to be controlled easily. The substratum in which they are planted tends to be a mixture of peat and ground bark and the containers can vary in size (Van Lerberghe and Balleux, 2001). Containerized plants are a little bit more expensive to produce than bare rooted plants, but the advantages are evident in terms of reduced risk of damage during transplantation, transport and handling (Van Lerberghe and Balleux, 2001). If appropriately selected species are used (e.g. pines and cedar), the container method offers higher survival rates than the bare rooted method. Another advantage for this method is that the potential transplanting period is five months longer than for bare rooted plants; containerized plants can be transplanted from middle of September to middle of June. However, containerized plants do require more humidity during their storage and transplanting period (Van Lerberghe and Balleux, 2001).

When comparing the different planting methods, it can be concluded that cuttings harbour the highest risk of failure (Guidelines, 2011), but the success of a SRF plantation depends more on the quality of the planting material than on the planting methodology.

KENYA

Plant Breeders' Rights (PBRs) became operational in 1975 under the Seeds and Plant Varieties Act (Cap 326) of 1972. The rights are granted by the State to protect the proprietary rights of plant breeders with regard to breeding and discovery of new plant varieties. A grant of Plant Breeders' Rights for a new plant variety gives the holder the exclusive right to produce for sale and to sell propagating material of the variety. In the case of vegetatively propagated fruit and ornamental varieties, Plant Breeders' Rights give the holder the additional exclusive right to propagate the protected variety for commercial production of fruit, flowers or other products of the variety. Currently, the patented eucalyptus trees are only produced for research as per agreement with the supplier and no multiplication for sale can be carried out. Mutual respect of the agreement between the supplier and the recipient of the material currently seems to be the case. Such agreements and national support for plant breeders increases the likelihood that quality standards are met when dealing with planting material.

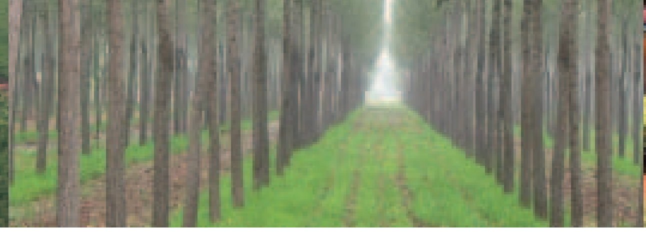
The quality of imported planting material quality depends largely on the consumer and the space in the container used for carriage: the logistics of handling the material determines to a great extent the size of material. In one case, rooted cuttings of eucalyptus were obtained from South Africa when they were 15 cm in height, 5 mm in diameter, with leaves and buds; these were ready to be planted directly in the field.

The choice of species depends largely on the end product, the prevailing climatic conditions, and the growth rate. According to end use there are several factors to be taken into account when selecting tree species for fuel wood, construction materials (timber/poles/posts) and/or fodder purposes. It is recommended to try out selected tree species before wide-scale planting because the overall growth performance depends on a complexity of factors including rainfall, temperatures, soils and their interaction. In Kenya, trials are carried out usually on small plots of public land and on several farmers' land under diverse soils and land uses in potential growing sites. The trials provide important information regarding the growth performance of the species under various management regimes. It is also essential to evaluate the effect of the species on yield of agricultural crops when intercropped. This is because the majority of farmers cannot spare a site with young seedlings spaced out widely across a large area without any intercrops during the early years of establishment and yet be expected to weed the seedlings. Land holdings are generally small and, thus, intercropping is a common practice on farms.

In Kenya, seedlings are mainly used for tree planting. Selection of seedlings is usually based on the following criteria:

+ Size of seedling
+ Susceptibility to pests and disease
+ Growth vigour
+ Availability in required quantities
+ Genetic diversity

Seedlings are often sourced from farmer owned nurseries (Figure 11). Seedlings are planted in prepared land, whereby holes are manually dug for the seedlings (Nangole and Lamond, 2011).



CHINA

EUROPE

INDIA

In India, planting material should fulfil the following criteria:

+ Fast growth
+ High establishment rate
+ High biomass production
+ Compatibility with associated crops
+ Deciduous nature
+ Insect, pest, disease tolerance/resistance

Deciduous species can be raised bare rooted during winter months, whereas, evergreen species should be planted with an earth ball around the roots or by preparing stumps (shoot cut at 5 to 10 cm to reduce transpiration loses) and preferably during the rainy season

Tree species which are well suited to local agro-climatic conditions and meet the needs of the local communities should be prioritized. Although exotics like poplar, eucalyptus, leucaena, salix and robinia have excelled in terms of productivity, they need thorough testing for at least one generation for their ecological implications.

CHINA

Due to its rapid growth and high yield Poplar spp. are the most important SRF species in China. The wood is mainly used to produce plywood and medium-density fibreboard (MDF).

The use of certain species depends on locally specific conditions and end use. The main end uses are fuel wood, timber, poles, posts and fodder. As well as tree characteristics, the quality of seedlings is also very important to assess when a high quality end product is required.

Poplar seedlings, for example, should meet the following demands:

+ Straight growth
+ Uniform (upper and lower)
+ Normal terminal bud development
+ Well developed root system
+ Lateral root of annual seedling > 20 cm, biennial > 30 cm

Abnormal seedlings (such as distortion, etc.) and seedlings with mechanical injury should not be planted. China sets national standards for the major afforestation species' seedlings, including 12 poplar species (Table 7).

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Higher variation of clones adapted for specific soil, ground water and climatic conditions.
2. Identification of optimal planting material (high biomass productivity, high tolerance to adverse environmental conditions) for fuel wood, charcoal, pulp paper and board industry to fulfill rising demand in the future.
3. Identification of optional plant species with additional side benefits (livestock fodder, financial benefit).
4. Introduction of exotics: potentials and risks.

Table 7: National standards for grades of poplar seedlings (Source: National Standard of the People's Republic of China GB 6000-85).

POPULAR SPECIES	SEEDLING SPECIES	SEEDLING AGE	QUALITY GRADE 1ST GRADE STEM BASE DIAMETER CM >	HEIGHT OF SEEDLING CM >	2ND GRADE STEM BASE DIAMETER CM >	HEIGHT OF SEEDLING CM >	3RD GRADE STEM BASE DIAMETER CM >	HEIGHT OF SEEDLING CM >
Populus tomentosa	Graft	2≈0	3.00	400	2.00≈3.00	300≈400	2.00	300
	Transplant	1(2)≈1	3.50	400	2.50≈3.50	300≈400	2.50	300
	Cover plant	2≈0	2.50	300	1.50≈2.50	200≈300	1.50	200
Populus cathayana	Cuttings	1(2)≈1	2.50	300	1.50≈2.50	200≈300	1.50	200
Populus x euramericana cv.'Sacrau79'	Cuttings	1≈0	2.50	300	1.50≈2.50	200≈300	1.50	200
Poplar69' Poplar72'	Cuttings	1(2)≈1	4.50	450	3.50≈4.50	350≈450	3.50	350

3.5 Planting

EUROPE

PLANNING THE PLANTING

:: CHOOSING THE ROTATION PERIOD

The choice of the period between two harvests (rotation period) depends on:

+ Tree species
+ The planned usage of wood and market situation
+ Available harvesting method
+ The site and local climatic condition
+ Availability of machines and staff during intensive times like cultivation in the first year and harvesting time

For an energetic use of the wood the periods are relatively short (3 to 4 years) with a higher density of planting. If the aim is timber, the spacing is wider and the rotation period is usually eight or more years. The shortest rotation period in practice is about 2 years. The longest rotation period is difficult to assess due to the transition of SRF to forestry which is defined in some countries by law. For example, in Germany the maximum rotation length for SRF is 20 years – after that the plantation turns into an illegal forest by definition.

By choosing a relatively short rotation period there are certain aspects which should be taken into account; for example, the higher percentage of bark leading to higher ash content per ton of dry matter. Furthermore, shorter rotation periods increase nutrient depletion of the soils and frequent use of heavy machinery increases the risk of severe soil compaction. An advantage of having longer rotation periods is avoidance of the abovementioned risks, but a disadvantage is the limitation of harvesting methods due to larger stem diameters.

:: PLANTING SPACING

There are different factors which influence the choice of spacing within a plantation, for example, wider spacing will lead to wider stem diameter of the trees and the width required will depend on end usage. The harvesting technique is likely to also dictate spacing requirements; in the case of mechanical harvesting, it must be ensured that there is enough space for turning the machines (Guidelines, 2011).

The number of trees planted depends on the geometry of the field and field margins. The planting density may vary between 1,800 and 18,000 plants per ha. In Poland there are sometimes 30,000 plants/ha as they mainly harvest manually and, therefore, do not need such wide spacing. It should be taken into account that a high planting density can have negative impacts on growth performance of trees and natural thinning in such cases has been observed.

:: TWIN ROWS VS. SINGLE ROWS

Twin rows are planted with a distance of 0.6 m x 0.6 m between the twins and 3 m between the twin rows. For single row planting the distance can be 3 m x 3 m (Alasia, 2006) or 0.5 m x 3 m (Alasia, 2006). Recommended planting spacings for willow and poplar are given in the Table 8 below.

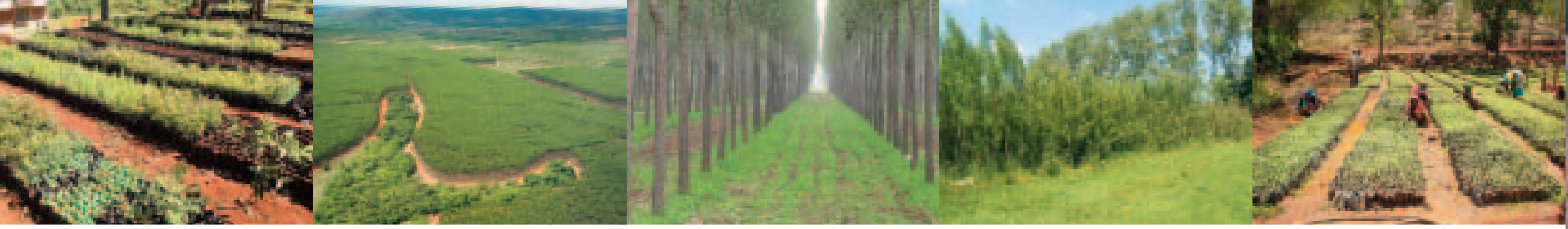


Table 8: Recommended planting spacings for single and twin rows of willow and poplar depending on the rotation period (KTBL, 2006; Best Practices, 2011).

ROTATION PERIOD [A]	DISTANCE BETWEEN SINGLE ROWS [CM]	DISTANCE BETWEEN DOUBLE ROWS [CM]	SPACING WITHIN THE ROW [CM]	PLANTS/HA	HARVESTING METHODS*
		POPLAR			
1-3	90		50-100	111,111-22,222	AM
1-3		75+150-200	50-100	7,273-17,778	FS, (AM), (MB)
3-5	90		50-100	111,111-222,22	AM
3-5	150-200		50-100	5,000-13,334	AM, (FS)
3-5		75+150-200	50-100	7,273-17,778	(FS), (AM)
5-10	150-200		100-200	2,500-6,667	FB, (SH), (MM)
>10	300		200	1,667	FB, MM, (SH)
		WILLOW			
1-5	90		50-100	111,111-22,222	AM
1.5	150-200		50-100	5,000-13,334	AM, (FS)
1.5		75+150-200	50-100	7,273-17,778	FS, MB, (AM)

* **AM**...cutting-chopping unit; **FS**...field chopper with cutting unit; **FB**...cutting and bundling
SH...a wood chipper that picks cut rods with a front pick up drum; **MM**...motor-manual

:: TIMING – WHEN TO PLANT?

Planting is mostly done during springtime in landscapes with a short autumn and a cold winter (Van Lerberghe and Balleux, 2001). According to such climatic conditions, cuttings should be planted as early as possible. By doing this, the plant becomes well developed and able to resist potential dry periods in spring and summer. It is important that the buds are not open when they are planted because it increases the risk of them dying than when they are planted with 'sleeping' buds. Although early planting is recommended, it does come with the danger of late frosts, which has a severe impact on poplar. A general rule for planting is that cuttings should be planted when farmers sow the corn.

Autumn planting is recommended for areas that have a late autumn and a mild winter. The generation of roots of bare rooted plants is good during that time and there is a lower risk of dehydration (Van Lerberghe and Balleux, 2001). Planting in autumn can be done with cuttings, rods and bare rooted saplings.

:: REPLANTING AFTER FAILURE – FILLING THE GAPS

Replacement of failed plants with cuttings or rods poses some difficulties as the young trees have to compete with the older and well established trees for resources; this can result in high loss rates. Replanting is more successful when replanting larger areas instead of small areas or single replacement (Hofmann, 1998). Light soils are beneficial when replanting due to encouraging faster root development in the young trees, but, in general, replanting should occur as soon as possible after the initial planting of the whole site.

If deviations from a normal growth and appearance are obvious in the early phase, replanting should be performed immediately as during a timeframe of about 2 to 4 weeks after the initial phase is most promising. Furthermore, this will ensure a homogenous plantation and avoid potential biomass losses. This method is called 'beating up' and requires a back-up of seedlings/cuttings. The amount of back-up plants that should be stored 'just in case' can be estimated by consideration of species specific survival rates (Guidelines, 2011).

:: PLANTING ON INCLINED AREAS

There are different ways of dealing with inclined areas and each has different aspects which need to be considered.

Plant rows following the contour lines of the site reduce the risk of erosion due to minimization of water run-off. However, in this case, the inclination may pose a problem for heavy machinery during harvesting because of the risk of overturning.

If the plants are planted in rows following the inclination, the slope should not be greater than 30% as it is not viable to harvest this area mechanically.

If the use of heavy machines is planned and/or the soil conditions are unfavourable, vertical planting rows should be aligned (Lewis, 2007).

Figure 12: Planting machine. Source: WENA, 2010.

PLANTING TECHNIQUES AND MACHINERY

In Europe, mechanized planting with specialized machinery is a common practice but planting techniques heavily depend on the planting material.

:: PLANTING OF CUTTINGS

The offset (distance between upper tip and soil surface) should not be greater than 20 % of the cutting length, especially if the cuttings are planted after the use of pre-emergent herbicides. The reason for this is that the cuttings will otherwise suffer from the herbicide residues.

In the case of cuttings being planted on sandy soils, no offset is recommended to reduce the risk of desiccation; if planting is done with machines the cuttings can then be topped with soil. During the first vegetation period, cuttings are exposed to two potential risks: 1) competition with the secondary flora (weeds), and 2) desiccation.

According to Best Practices (2011) there are certain measures that have been shown to increase the survival rate of young cuttings:

+ Watering the cutting 24 to 48 h before planting (Reeg *et al.*, 2009; FNR, 2010)
+ During planting the bark must not be damaged (only intact cambium ensures root and shoots development)
+ Cuttings have to kept cool and moist along the entire supply chain
+ Soil around the cuttings has to be compacted after planting

In general, planting of cuttings can be performed either manually or mechanically, but manual planting is carried out on smaller areas of up to 2 ha. For orientation purposes, the workers create parallel lines on which the planting is adjusted (FNR, 2010).

Large plantation (> 4 ha) sites are planted mechanically (Van Lerberghe and Balleux, 2001). Up to six persons put rods into an automatic cut and plant unit (Figure 12) and the machine then cuts cuttings from the rods before pressing them into the soil (FNR, 2010). These machines are available for poplar and willow. The advantage of these machines is that they have a high throughput (planted trees/hour). The planting process increases by increasing the speed of the towing vehicle, but it has to be taken into account that planting speed and planting quality is negatively correlated. This is mainly due to too much compaction of the soil around the cutting (planting furrow) which is especially challenging on heavy soil.

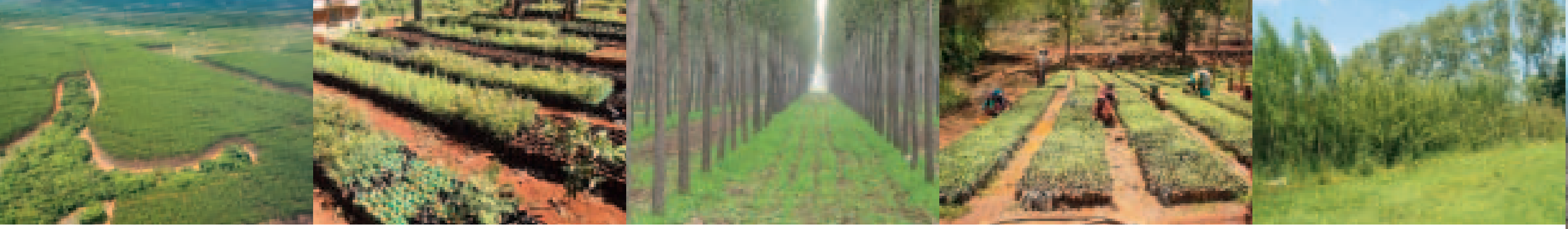
If mechanical planting is undertaken effectively and sensitively, the survival rate of the plants is higher compared to manually planted plants (Van Lerberghe and Balleux, 2001). This can be partially explained by the fact that mechanically planted cuttings are exposed to the air for a shorter time when compared with plants planted manually. Additionally, mechanically created furrows are beneficial for root development.

:: PLANTING OF RODS

The recommended planting depth for rods ranges between 30 and 50 cm for short rods and between 70 and 100 cm for long rods. Generally speaking, one third of the rod should be planted into the ground. The planting furrow for rod planting is created using a thorn pulled by a tractor.

:: CONTAINER PLANTS

Container plants are planted manually using a planting dibble. The plants are delivered in a small container with soil ball around the roots which helps to avoid desiccation during transportation.



KENYA

INDIA

KENYA

Trees in short rotation systems tend to be established on farms either as individual trees scattered across crop fields, in lines along farm boundaries, in rows along contours on the farm or in woodlots. **Spacing** of trees varies depending on individual preference of the farmer and farming system and therefore do not follow any specific spacing systematically carried out.

Tree size and growth rate is heavily influenced by different spacing and, therefore, spacing will differ depending on the desired end product. Maghembe *et al.* (1986) found that the closer the spacing, the higher the overall biomass and volume of wood produced due to the higher number of trees in a given area. However, diameters of individual trees were favoured by wide spacing. Heights of individual trees were least influenced by the spacing. In terms of wood products, wide spacing is favoured for producing bigger trees that allow the farmers to utilize the wood for a wider range of potential end products. In close spacing, the size of individual trees remains small and, therefore, provides bulk biomass that can only be used for chips, pulp and fuelwood. For coppicing trees where fodder is the main product, close spacing is favourable. Besides the tree products, wide spacing allows the growing of agricultural crops between trees, an aspect favourable with small-scale farmers who often have limited land available to sustain their livelihoods.

In Kenya, **cuttings** are rarely used on farms and in public forests mainly because the field conditions are normally such that it is difficult to provide maximum care to all the cuttings to ensure high survival rates. Furthermore the rainy seasons are too short and unreliable to provide favourable conditions conducive for planting cuttings and full development of their roots. The usual practice is to obtain small cuttings from selected trees and root them in the nursery. Once they have developed into healthy seedlings they are transferred to the field like other seedlings. Among agriculture crops such as Napier grass and cassava, the stems are planted in a slanting position with at least two or three nodes in the ground to provide rooting points.

The use of tree **seedlings** is common in Kenya. In order to increase survival rates, only healthy and vigorously growing seedlings that have been hardened through reduced watering and root pruning are taken to the field for planting. The pits are dug before the start of the rainy season so that they collect water and are then covered and retained near the roots during planting. The actual planting is carried out after adequate soil moisture build up but early enough in the rainy season to maximise the period the seedlings can benefit from the rains. Thus, the period in which the seedling can benefit from a sufficient water supply is increased. All seedlings are potted and the containers are removed next to the planting pit to reduce the time the roots are exposed to the atmosphere. The areas around the planted seedlings are weeded to remove competition for water and nutrients. Mulching is also done using vegetation residues or small rocks whilst water harvesting structures are constructed to capture and retain any runoff that may occur in the field.

INDIA

Though various tree species are planted every year, a majority of the plantation programmes consist of short rotation species like *Eucalyptus spp., Populus deltoids, Albizia spp., Prosopis juliflora, Leucaena leucocephala, Melia spp., Robinia pseudoacacia, Gmelina arborea, Anthocephalus cadamba, Acrocarpus fraxinifolius, Salix alba, Ailanthus excelsa, Casuarina equisetifolia, Terminalia arjuna, Acacia spp., Bombax ceiba, Bamboos*, etc. (see chapter 3.3: Genetic material).

Spacing of trees on a plantation depends on the nature of the species, objective of planting and purpose of end product (Table 9). Growing trees in larger spaced plantations produces higher volumes and thinning helps in producing good quality wood. Adverse effects of trees on any associated crops decrease with increasing tree spacing and even the competition among trees is reduced.

In India, the planting is mostly done manually which generates much rural employment (Figure 13). In any plantation programme, the labour component accounts for about 60 to 70 % of the total expenditure. Moreover, the bulk of the labour is unskilled or semi-skilled such as: nursery work, sowing, planting, weeding, watering, hoeing, and after-care.

Site conditions influence the treatment of the plants as well as site preparation before planting. Under waterlogged conditions, the earth is piled up or raised bunds/mounds are made for planting on to keep the plants away from direct contact with stagnating water. Even in industrial plantations with purposes of phyto-remediation of industrial waste-water, planting on bunds is recommended and followed. Soil is also piled up to protect the plants against strong winds; this is more specifically on light soils. Certain enhancers, e.g. mycorrhiza, are used to increase the productivity of plantations. Natural enhancers used are:

+ *Acacia nilotica*: Vesicular Arbuscular Mycorrhizal (VAM), rhizobium and phosphor-bacterium supports establishment and growth
+ *Leucaena leucocephala*: VAM fungal inoculation supports establishment and increases growth performance and the vigor of the plant to overcome potential adverse conditions
+ *Tectona grandis*: Application of Azospirillum and phosphorus-bacterium increase the heights of plants
+ *Dalbergia sissoo*: Inoculation with rhizobium and VAM supports growth

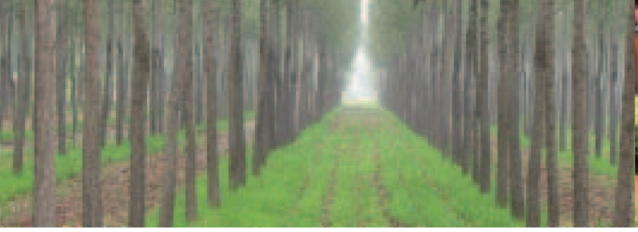
However, most plants receive a treatment against insect-pest and certain diseases before planting. In India, termites are a big problem so plants and the soil are treated against termites before planting takes place.

In India, the main constraints regarding planting are: inadequate research activity, institutional limitations in extension support, lack of good quality planting material, as well as lack of financial/trained human resources.

Figure 13: Raising cuttings. Source: PAU, 2011.

Table 9: Distribution of SRF tree species according to purpose in India.

SPECIES	ROTATION LENGTH [YEAR]	SPACING [M]	PURPOSE
Acacia auriculiformis *A. mollissima*	10–12	2 × 2, 3 × 2, 2.5 × 2.5	Biomass for pulping
Populus deltoides	5–8	5 × 5.4 × 4, 5 × 4	Raw material used in plywood and paper industry
Leucaena leucocephala	2–3	2 × 2	Pulp wood and energy plantation
Melia composita	8–12	6 × 6	Timber
Robinia pseudoacacia *Morus alba*	15–20	3 × 3 3.0 × 1.5	Energy, fodder and sports industries
Prosopis juliflora	3–15	2 × 2, 2 × 3, 3 × 3	Energy and site amelioration
Gmelina arborea	10–12	3 × 3, 6 × 6	Pulp and paper
Eucalyptus hybrid	3–10	1 × 1, 5 × 5 Various spacing depends on end use	Firewood Pulpwood and poles Saw logs | Windbreak and shelterbelts
Anthocephalus cadamba	10–15	5 × 5	Plywood
Ailanthus excelsa	11 to 16	3 × 3, 5 × 5	Production of biomass | Timber production
Casuarina equisetifolia	4 7–10	1 × 1, 5 × 5 Various spacing depends on end use	Poles Fuel wood Pulp | Agri-silviculture
Terminalia arjuna	10	5 × 5	For industrial purpose and making agricultural inputs
Bamboo *Salix alba* *Cryptomeria japonica*	4 onward 10–15 5–10	5 × 5, 4 × 4 5 × 5 2.5 × 2.5	Raw material in industries Small timber/sports industries The fuel wood and timber





CHINA

In China, the main species of SRF are poplar, eucalyptus, Paulownia, willow and *Morrisonicola*, while the predominant shrub species used for SRF is Seabuckthorn. The spacing of these species mainly depends on the end purpose (Table 10). The spacing within the plantation has certain effects on establishment, development and the productivity of the production chain.

If the plant spacing is too wide, a young aged forest would separate from each other and the woodlands would be bare and covered with weeds. If the plant spacing is too dense, a young aged forest would have premature canopy closure and competition for limited nutrients. Spacing effects growth parameters (height-growth, radial (DBH)-growth, volume, root development) and wood quality parameters (trunk's straightness and roundness).

Certain aspects of pre-planting and planting management and technology affect the success of the wood production:

Table 10: Distribution of SRF tree species according to purpose in China.

SPECIES	DETAILS	PLANT SPACING [M × M}
Poplar	*Chinese white poplar*	Small dimension wood: 2 × 3 or 3 × 3 Large dimension wood: 4 × 4 or 4 × 6
	Occidental poplar	Small dimension wood: 3 × 3 or 3 × 4 Large dimension wood: 2.5 × 7.0
Eucalyptus	*Urophylla U6 hybridized eucalyptus LHI hybridized eucalyptus east China sea No 1*	2.5 × (1.6–2.0)
Paulownia	*Urophylla shilling No 1*	1.2 × 3.0, 1 × 3, 1.2 × 2.8, 1.0 × 2.8
Morrisonicola	Based on forestlay equal stress on forest and grain	5 × 55 × 104 × 30
Seabuckthorn	---	1 × 2
Poplar	Forest for water and soil conservation, economic forest	2 × 3, 1.5 × 4.0, 3 × 2, 4.0 × 1.5

:: LIFTING

The time for lifting is mostly during seedling dormancy, before sprouting in springtime. Before transplanting takes place, the seedbed is watered two or three days in advance to prepare for lifting out the seedlings. The depth of dredging is dependent on the depth of different trees' roots - deeper than the roots by about 5 to 9 cm works well.

:: PRE-PLANTING TREATMENT

Seedlings of deciduous broad-leaved wood are treated as bare-rooted seedlings. First, moist materials are put on the wrappers and the seedlings are laid on top of them, roots against roots. Then the moist materials should be added among the roots; this could be lichen or wet wheat straw. At the end, the seedlings are folded, rolled and combined into bundles of an appropriate weight.

Seedlings of coniferous trees and a majority of evergreen broadleaf trees are susceptible to lost water balance in their bodies when lifting due to high transpiration and root damage. To avoid this, these seedlings are lifted with soil balls around the root and should be wrapped with plastic films, mats or straw bags.

:: PLANTING TECHNOLOGY

Before planting, the site is prepared according to the site conditions and plant species (chapter 3.2: Preparing the soil). The best time for planting will differ across regions in China.

The seedlings are put into the ground vertically with unfolded roots. The soil around the seedling is then compacted and covered with a layer of topsoil. All of this is carried out manually.

:: ENHANCERS

China uses several types of mycorrhiza to enhance growth and development of plants. When introducing a new plant, relevant mycorrhizae and/or plants that obligate mycorrhizae such as pine should be introduced at the same time. Using mycorrhizae in SRF can not only increase survival rate but also the production and the ability to absorb nutrients. In areas which are very hard for conventional planting (barren soil or wasteland) the survival rate can be greatly increased by choosing suitable plants and well-adapted ectomycorrhizae. This can accelerate vegetation recovery and prevent soil exhaustion and environmental deterioration. Furthermore, mycorrhizae play an important role in prevention and control of plant root diseases. Ectomycorrhizae support the plant when attacked by soil-borne plant pathogens. Arbuscular mycorrhizae are mainly present in areas of forests, field crops, vegetables and flowers. They can encourage plant growth, increase production and improve quality.

BRAZIL

In Brazil, the most used species for the pulp and paper production as well as for the iron and steel industry are the *Eucalyptus spp.* Eucalyptus is planted in several spacing patterns: 3 × 2 m, 3 × 3 m and 3.0 × 2.5 m, representing an area of 6 to 9 m^2 per tree. In dedicated timber plantations, spacing varies between 3 × 2 m and 3 × 3 m to 3 × 4 m and 5 × 5 m after growth stabilization (at about 7 years); thinning is applied to the remaining trees. For timber production on a 15 to 20 year rotation, spacing is larger starting at 5 × 5 m from implementation.

SRF plantations will vary between 3 × 2 m to 4 × 4 m and harvesting occurs at the age of 18 to 25 years whilst the plantation is thinned in years 8, 12 and 16. *Pinus spp.* is mostly used for pulp and paper, timber, saw wood and energy.

The most important factor influencing spacing is the end use of the wood product. If the wood is to be used for energy and pulp the plantations tend to have higher densities, whereas, for timber production stocking rates are smaller in order to increase stem diameters. Nutrient availability also influences the plantation spacings; plantations with adequate nutrients allow denser spacings. SRF spacing influences tree growth rates, wood quality, forestry rotation, implementation practices, stewardship and harvesting.

The plantation material mainly consists of seedlings produced out of cuttings. These cuttings are produced at nurseries in 'clonal gardens'. Seedling production follows very strict quality controls that help to guarantee the seedlings' survival. Enhancers like mycorrhizae are used mainly when plants are planted on poor sites with nutritional deficits. If seedlings are in the field, phosphate is applied to every pit to promote the growth of the seedlings.

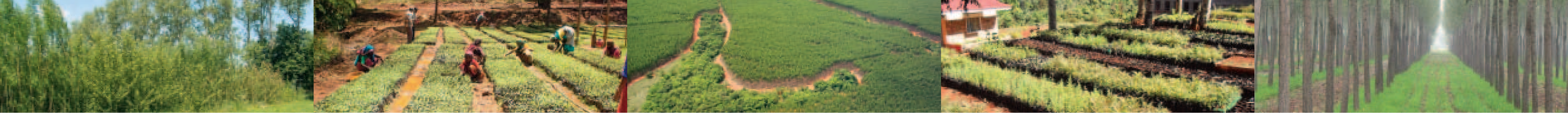
In many plantation areas e.g. the State of Minas Gerais, the declivity of the terrain allows mechanized activities such as subsoiling, application of herbicides and fertilizers and irrigation. In the regions where mechanization is possible, planting is done using a machine which opens the soil, applies the fertilizer and places the seedling. But, even in this case, it is still necessary that a worker takes the seedling out of the plastic cover and places it on the machine.

For areas with steeper slopes, the abovementioned activities must be performed manually. In the case of planting, for example, the opening of pits and the placement of seedlings into the ground are all done by hand.

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Optimal geometry (spacing) for different wood end-uses and coppice management.
2. Making use of available niches on farms and workable composition of species.
3. Pure and mixed plantation: productive potential, planting of mixed material (e.g. different clones in one field) vs 'homogenous' monoclonal parts in one field.
4. How best to establish a plantation under organic farming rules?



3.6 Cultivation and maintenance

EUROPE

:: CLEANING THE LAND

The reason for cleaning the land is to control potential competition. Grasses and brushwood are competitors for nutrients and water, therefore, one of the main requirements for successful farmland afforestation is to clear the land of these species before planting up a plantation. One problem in the initial years of plantation establishment is that weeds often grow faster than the saplings, which can lead to decreased growth rates or even death of saplings if left uncontrolled.

A complete removal of the existing vegetation should be avoided on steeply sloped sites as well as on sites exposed to harsh climatic conditions. If these aspects are taken into account, severe erosion and sapling dehydration can be avoided or at least reduced (Van Lerberghe and Balleux, 2001; Lewis, 2007). The following methods and techniques are applied in European countries to control weeds and brushwood.

:: MECHANICAL AND MANUAL TREATMENT

Manual weeding is not so common in European countries on commercial plantations but in some areas it can still be usefully practiced.

A mechanical technique used for weeding is **shallow ploughing and harrowing**. Ploughing (10 to 30 cm in depth) is done in order to reclaim the soil and enhance its structure and to shred the grass layer. The following machines are frequently used:

+ Disc harrow
+ Heavy cultivator
+ Rotation cultivator

Another method includes **flailing and mulching** (Figure 14). The use of a motor scythe for flailing between the rows of a plantation is not recommended as it harbours the risk of damaging the bark sprouts. One mulching technique involves the use of mulching foil which creates an artificial soil cover around the trees; it acts as an alternative to work-intensive hoeing and protects the trees for about three years (Best Practices, 2011). Natural mulching also occurs when dead leaves are left on the ground.

If the trees survive the first year they are able to compete effectively against the weeds.

Figure 14: Mulching – an effective method of weed control. Source: Christian Siebert, 2010.

:: CHEMICAL TREATMENT

Chemical treatment of weeds is carried out by spraying approved chemicals on the area. Different types of **herbicides** may be applicable; therefore, it is useful to have some knowledge about the unwanted flora so that the most effective herbicide can be applied. It is important to consider potential negative impacts on the environment and avoid herbicides unless it is very necessary.

To choose the right dosage, enhanced knowledge about the soil is beneficial as the dosage may need to be higher on soils with high percentages of organic matter than on light or chalky soils.

Herbicides can be classified into preventive and curative herbicides:

+ Preventive herbicides are anti-germinal herbicides. This type is applied on clean soil. Germinating seeds and very young plants absorb the herbicides through their roots or aerial parts. This herbicide does not affect developed plants (Van Lerberghe and Balleux, 2001).
+ Curative herbicides can act in 2 different ways. A contact herbicide destroys the tissue after application. A systemic herbicide penetrates the plant walls and cause damage to certain cell organelles.

Although herbicides are available as liquid, soluble crystal or soluble powder, all types are applied diluted in water mechanically or with pressures sprayers through fan nozzles. These sprayers are usually mounted on tractors. The use of herbicides is strictly regulated at the EU and national levels.

:: CUTBACK AND PRUNING

Cutback after the first year is beneficial due to the following impacts on tree growth:

+ Inducing coppicing
+ Compact tree crown
+ Improved crown-root ratio

Cutback of willow is a current practice in Poland (Best Practices, 2011) and in the U.K. it is recommended to carry out a cutback in the planting year (Defra, 2004). Pruning is done in order to maintain the shaft of the tree for timber and/or to obtain fuel wood or green fertilizer. Pruning is mostly done manually for species which are not self-pruning (e.g. eucalyptus) (Guidelines, 2011).

KENYA

Short rotation forests are important in Kenya for the supply of wood products to an ever increasing population; they serve to reduce pressure on the natural forests and woodlands whose growth rate is minimal and therefore difficult to restore once destroyed. In public forests and on farms, it is important that SRF trees are maintained with minimal competition to encourage fast growth. For different end products, the planting density, maintenance and the rotation age are clearly spelt out for plantations established on public land.

In Kenya, there are two forest departments that provide national documents guiding the management of plantations, while in every forest station a local document (the Compartment Register) is maintained with respect to every single plantation. There are also Forest Department Technical Orders which are species specific guidelines for the forester/farmer in terms of what to do from establishment of the plantation, maintenance such as weeding, the silvicultural operations to be carried out, and eventually how the trees should be assessed and harvested for specific end uses.

Generally, weed control is undertaken through complete cultivation of the planting site. In public forests the 'taungya' method was used in the past where farmers were allowed to grow agricultural crops on forest land next to the seedlings. Intercropping normally took three years after which the tree canopy closed and adversely affected crop yields. Currently, the same system has been modified to make it more people friendly under the acronym PELIS – Plantation Establish for Livelihood Improvement System, where cultivators are compensated for their labour input. On smallholding farms, trees are commonly established together with agricultural crops and are, as a result of this, weeded. In the case of woodlots on farms, the plots are slashed and individual trees weeded at the base.

Weed control is carried out differently according to specific site conditions:

+ Waterlogged sites: vegetation is slashed regularly to avoid shading whilst planted seedlings and the seedling base are spot weeded.
+ Dry conditions: sites are weeded before the rainy season to encourage percolation of water and weeded again after the rain in order to remove the weeds and also to create a porous layer of soil on the surface which cuts off capillarity action and water holding capacity.
+ Weedy conditions: normally these are sites that are used agriculturally as they are highly fertile. At such sites, trees are intercropped with agricultural crops and, thus, are weeded at all times during their establishment years by the cultivators.

During the cultivation period, soil is actually loosened to allow entry of water where hard crusts have developed after rain events. A porous well aerated layer is thus formed which breaks capillarity action that transmits soil moisture to the atmosphere. Soil is loosened to conserve moisture and allow deep penetration of roots. Mulching is not used in short rotation forests deliberately. However, in most situations where trees are intercropped with agricultural crops, plant residues are placed along the tree rows where they act as mulch. Plant residues may be mixed with manure and/or livestock urine for quicker decomposition and extra benefits for the soil. In the dry areas, however, mulch from plant residues attracts termites that may become a menace during the dry season as they attack the succulent stem.

Figure 15: Manual weeding. Source: PAU, 2010.

INDIA

Weeding is mainly implemented in the initial stages of plantation establishment, but also to some extent in established fields. The following integrated measures of weed control are applied:

- Manual weeding (Figure 15)
- Chemical sprays
- Herbicide application (pre- and post-monsoon)

In the case of chemical weeding, either contact herbicides like 'Gramoxone' or systemic herbicides like 'Glycel' (Round Up) are used. Some invasive weeds, e.g. Lantana and Parthenium certainly have become problematic in natural forests as well as in plantations. Their control is challenging and cost effective strategies have yet to be developed to check encroachment on plantation areas.

Mulching is very common in Indian fruit and vegetable production system, whereas, it does not play a comparable role in agroforestry. In forest plantations, it is performed on stressed sites at a limited scale to conserve water and on sloping lands to conserve soil and water. Furthermore, mulch provides nutrition to the soil and reduces soil temperature fluctuations. One disadvantage is that mulch attracts termites and they are not selective and damage the crop also.

CHINA

In China, there are several documents and guidelines for farmers/foresters concerning management and cultivation practices for SRF.

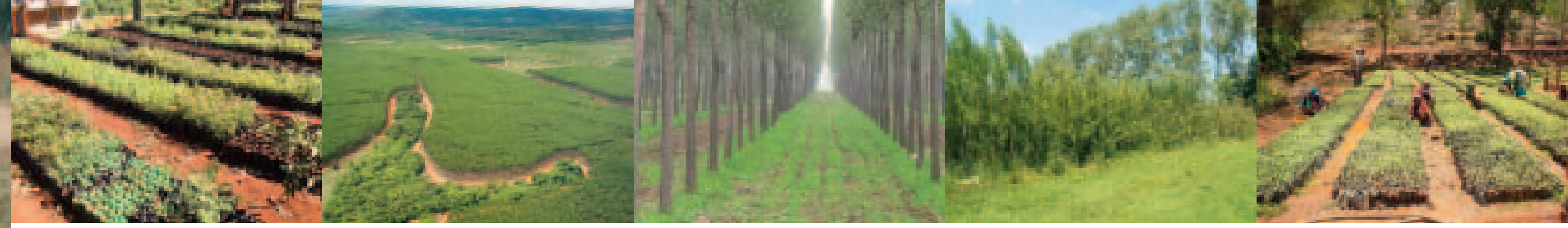
Weeds can be controlled by following three different strategies: First, it is possible to change the environmental conditions from optimal to sub-optimal for the weed. This strategy goes hand-in-hand with optimizing the conditions for the agricultural crops and/or trees. This can be achieved through certain management activities (fertilization, spacing, water management etc.) being applied at the right time. If performed properly, the weed growth can be depressed whilst enhancing the growth of the actual culture plant.

A second possibility offers mechanical or chemical treatment which has to be applied based on the site conditions and available agricultural technology. Mechanical treatment can work well on its own or in combination with herbicides and/or manual weeding. Machinery is used for working the topsoil to cut off weed roots and to interfere and inhibit weed growth in order to control the weed population. Chemical treatment can alleviate the intensity of labour when short of manpower, however, the risks of herbicides are well known and chemical treatment should be approached with caution. The third strategy involves mulching as a management tool to improve site conditions. This practice is known very well from Chinese fruit and vegetable production, but it is not applied in forestry and agroforestry systems.

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Monitoring and growth estimations of SRF systems (Ali, 2009).
2. Impact of ash and sewage sludge fertilizer (Walmsley, 2008), sustainable dosage aspect (Felker, 1984; Swedish Forestry Agency, 2006; Larsson, 2003). Waste flows, and life cycle assessment, flow of nutrients and heavy metal compartments.
3. Usability of under-foot fertilization, storage fertilizer, economic point of view regarding rising fertilizer costs, limits for economic performance. Fertilizer application in general.



3.7 Water Management

EUROPE

Water scarcity is particularly an issue in eastern regions of Germany and England. In Sweden there have been studies examining the use of waste water to address this issue (Dimitriou, 2005). Water management starts with the choice of tree species. Species with high water demands should be avoided. Irrigation is not recommended in large scale plantations as long as water is not a limiting resource (majority of cases). Nevertheless, irrigation can be important and beneficial during the initial phase of SRF. If irrigation is planned, there are often national regulations regarding distance between field and adjacent water bodies which would need to be checked (Guidelines, 2011).

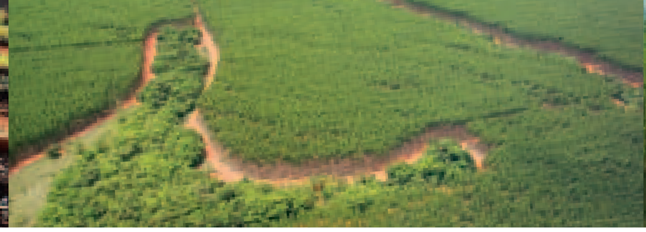
Irrigation can be performed via drip irrigation, whereby, superficial tubes and installed trippers deliver the water directly into the soil. The direct tripping into the root area reduces losses due to evaporation and sinking of water.

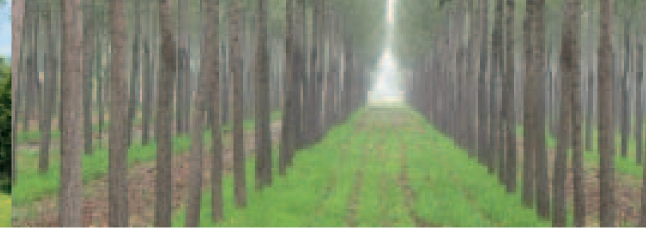
Mulching offers a possibility to conserve water as it prevents the soil from drying out rapidly. Another strategy to save water, at least with small-scale SRF, is bottle irrigation instead of run-off irrigation. The use of wastewater harbours difficulties due to potential contamination of verging water bodies and the barred use on food producing areas.

Irrigation in poplar plantations is often carried out in order to minimize the risk of failure in the initial phase of the first and the second year establishment. An optimal water supply during that period is beneficial as it encourages optimal root development.

In general, irrigation of SRF to increase yields is not recommended for European areas as the cost-benefit-ratio is poor (Petzold *et al.*, 2009).

Figure 16: Watermanagement in Brazil. Source: Plantar, 2009.




KENYA

As water is a limited resource in Kenya, the use of water is regulated by certain rules and regulations at a national level. Especially during the dry season farmers in the upper areas of the main water catchments in the country are prohibited from irrigating their farms; this is in order to allow water to flow downstream. More restriction is being placed on use of surface irrigation as most water is lost through seepage and evaporation between its source and point of use. For pipe-based irrigation systems the amount of water one may transport and use is limited and regulated as well.

Planting of trees for the purpose of harvesting is discouraged along water ways with strips of at least 30 m maintained – the stipulated distance increases in steeply sloped areas. *Eucalyptus spp.* is not to be planted near water ways or areas where wet conditions are deliberately maintained such as rice paddies.

The most common irrigation system is rainfed run-off irrigation. It involves a construction of water harvesting micro catchments for individual trees in sites with a slight slope in the dry lands. The structure can be either circular-, square- or V-shaped with the seedling planted at the lower part of the catchments.

Other frequently used methods include bottle watering. Bottles are sunk into the ground next to the tree seedlings, refilled regularly with water, and covered to reduce evaporation. The covering of the bottle ensures the water does not get hot and thus scorch the roots of the seedlings. The water penetrates directly to the seedling and therefore the only losses that occur are through evapotranspiration. This method is applicable on sites with a permanent water source close to the planting site.

Another method of irrigation besides bottle watering is the use of stone or sand mulch around the seedlings. This method is highly recommended for dry areas prone to termites. Sand or rocks are accumulated around the seedlings before rain events; this leads to water being accumulated rather than lost during precious downpours. The method is used in relatively flat areas dealing with very limited rainfall.

Generally, there are no prescribed systems of draining very wet soils in forested areas in the country but many of these places will be planted with species tolerant of waterlogged conditions – *Eucalyptus spp.* will be planted at the edges and this continues draining the soil over a long period. In some areas, waterlogged sites are drained through digging of trenches and the water is directed to other areas that require the same commodity.

In Kenya, waste water from industries is either disposed through town council sewage systems or treated by the industry and thereafter drained into sedimentations pods and then released into rivers. Domestic raw waste water is drained through surface furrows into gardens where it is normally used for watering food crops. It is the main source of water for kitchen gardens that supply vegetables to homesteads, especially in urban areas.

Although farmers do practice rainwater harvesting, it is rarely used for trees (Figure 17). Trenches which collect rain water can supply crops with water for up to 2 to 3 weeks during periods of little rainfall (Nangole and Lamond, 2011). The water is mainly used for livestock and food crops.

Figure 17: Rainwater harvesting technique. Source: Genevieve Lamond, 2011.

CHINA

SRF/agroforestry irrigation is applied depending on the availability of water. The drip irrigation technique provides an excellent water-saving solution and is used in forests located in windy and dusty areas of China.

When introducing drip irrigation, the soil (20 cm) under the planted trees' roots should have a similar maximum water holding capacity as the surrounding field. Afterwards, the soil moisture needs to be kept at 70 % of field moisture-holding capacity. The irrigation regime then starts on day zero (planting) and lasts for 4 days. Intervals between treatments (on/off) may vary between three to six hours. This technique saves 50 % water compared to normal irrigation techniques while increasing the survival rate of the saplings considerably.

Chinese white poplar forests in some areas of North China only need to be irrigated during their growing season from May to June. In some dry areas and the desert, the use of root irrigation and subsurface drip irrigation method showed remarkable results when applied from April to June.

China has a lot of areas around rivers which can be described as waterlogged. Several common drainage methods are applied in order to make the land usable. Drainage techniques include surface and soil drainage as well as mouse-hole-drainage. Mouse-hole drainage is a low-cost, simple and highly efficient method and is suitable for heavy sticky soil with poor water permeability. However, there are still many problems regarding the research on different degrees of waterlogged areas. Further detailed studies are highly necessary.

In China, the use of recycled water (part of high grade domestic grey water after purification) just started a couple of years ago and is still in the experimental stage for most cities. However, the use of waste water can be classified into classes:

+ Recycled water used for urban landscaping, garden landscaping, road spraying, municipal engineering, industrial cooling, household flushing and car washing, all processes baring human skin contact.
+ Recycled water used by waste water treatment systems, built by water using units and residential quarters, which collect waste water from buildings in certain areas and reuse the water in the areas after purification.

Facing a series of severe problems such as deficient surface water due to exploitation of groundwater and water pollution, the use of recycled water to irrigate SRF may be acceptable and also beneficial. Research still needs to be done to evaluate existing problems in order to optimize the use of recycled water effectively.

INDIA

SRF species require intensive management including irrigation in order to increase their survival and productivity. There will always be constraints regarding the usage and wastage of water in general and domestic water in particular, and irrigation in SRF/agroforestry is applied depending on the availability of water. Some species like *Populus* require regular irrigation (every 7 to 10 days during summer and 20 to 25 days during winter months), whereas other SRF species are not sensitive to irrigation. Life saving irrigation is essential or planting has to be done during the rainy season. With additional irrigation SRF productivity is substantially enhanced. It has been found that SRF has very little impact on the water table but can add significantly to the overall land productivity (Zomer *et al.*, 2007). Making use of domestic and industrial waste water is a useful option in SRF, but has not yet been attempted to a significant degree.

WATER MANAGEMENT AND AGROFORESTRY

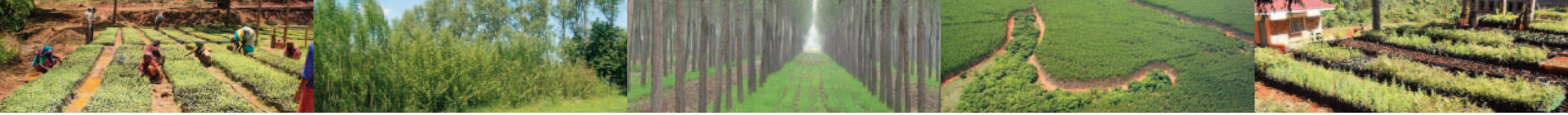
Agroforestry systems tend to have, beside their production purposes, several functions and services towards the environment. This is especially true if agroforestry systems are used within riparian buffer zones. In general, such systems can: function as filters for agriculturally used pesticides; lower nutrient and animal waste runoff, and hold back sediment during flooding. Beside this, additional positive influences towards aquatic organisms and wildlife in terms of providing shelter and food sources can be observed[1].

Agroforestry may also be used in management of water micro catchment systems in order to prolong the water run-off rate and increase infiltration, and reduce flooding impacts. Grasses or bushes may be used as understorey species and many different designs can be used to enhance the system. In this situation, the production of timber is not the most valuable part of agroforestry, but its service function of soil fertilizing, water conserving and shading. However, as stated in previous sections, trees must be chosen appropriately for local climatic and soil conditions, otherwise beneficial impacts may not be realized.

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Possible over-exploitation of ground water, impacts of precipitation and understorey management, optimization of eucalypt water consumption (Oliveira, 2009).
2. Optimizing water efficiency of woody biomass production. Selection of species/genotypes with low water and maintenance requirements; salt tolerant species; optimizing water retention in micro catchment systems. Management of saline and waterlogged soils for economic use.
3. Waste water management and options for wastewater, sewage and effluents filtering, irrigation with water from wastewater treatment plants.



3.8 Nutrients and Soil

EUROPE

Nutrients and soil play an important role within the economic success of SRF plantations to yield viable amounts of biomass. Required soil physical properties include good water storage capacity, well aerated conditions in the upper soil and no soil compactions. These conditions will facilitate sufficient water availability for the trees. SRF trees have rather high transpiration rates (Petzold *et al.*, 2010; Lamersdorf *et al.*, 2010). Thus, soil water household is a major factor influencing the growth. Despite the fact that the trees have a high demand on nutrient availability (compared to other forest trees), they are less demanding than most annual crops. Experiments have shown that poplar does not respond to fertilization by increasing volume increment (van den Driessche, 2008).

However, plantation areas are prone to soil erosion (by wind and water) during the first year and need an inter-row cover (Hildebrandt[2]) but later on they can serve as a protection measure (Coleman[3]). Beyond the mere exploitation of nutrients for their own requirements, SRF trees have the potential to extract hazardous elements from the soil. This can be a problem since the ash (especially cyclone ash) gets contaminated and cannot be recycled to the plantation. This offers a biotechnological option for remediation of polluted areas. The separation from a matrix (i.e. soil) and the higher concentration of heavy metals or radioactive elements in the anorganic ash allows for a space-saving disposal (Mirck[4], Paulson[5], Isebrands[6]).

Fertilization can be done with manure and/or mineral fertilizers. The aim is to enhance the fertility of the soil by modifying its physical, chemical and biological properties. Fertilization should provide optimal conditions for growth of current and future plantations. When applying fertilization the pH of the soil will be altered and reserves of minerals which can be then be absorbed by the soil are created (Van Lerberghe and Balleux 2001).

Before applying fertilizers, the nutrient state of the soil should be evaluated for key deficiencies. According to Lewis (2007) the state of nutrients should be monitored at the following times:

- Before planting
- After each harvest (rotation)
- Before recirculation to cropland

The nutrient status can be detected through leaf diagnosis (Bergmann, 1988, Makeschin *et al.*, 1994). For this type of analysis it is important that the sample is taken during the main growth period from the fourth, fully developed leaf of the highest shoot. The content of phosphorous and nitrogen should ideally be 1.8 to 3.0 mg/g and 18 to 25 mg/g, and 3.5 to 5.0 mg/g and 26 to 32 mg/g in willow and poplar, respectively (Bergmann *et al.*, 1988; Makeschin *et al.*, 1994).

There is a strong correlation between wood yield and removal of nutrients. The bigger the yield the more nutrients are removed from the soil (KTBL, 2006).

In order to avoid competition with weeds, fertilization in the first year is not recommended (Guidelines, 2011). The BENWOOD Guidelines also recommend an inorganic fertilization for the ensuing years after planting. To reduce fertilization costs, manure or sewage sludge may be applied depending on permissions and national guidelines.

:: NUTRIENTS RECIRCULATION BY LEAVES

A large percentage of nutrients taken up by the trees are recirculated into the soil via fallen leaves. A continuous growth of the root system enables the plant to reach nutrients in deeper soil regions and these nutrients are then brought to the upper soil by the plant and their falling leaves.

:: 'SITE'-PARAMETER

It is important that, as much as possible, removed nutrients are returned to the site. Lewis (2007) states that different parameters like species, site, rotation length, and yield all influence the net removal. Measurements showed differences in nutrient content of the same clones and same rotation period on different sites. Relating to the nutrient content of the clones, different yields were observed across sites.

[2] http://www.bfn.de/fileadmin/MDB/documents/themen/erneuerbareenergien/bfn_energieholzanbau_landwirtschaftliche_flaechen.pdf

[3] http://www.srs.fs.usda.gov/pubs/ja/ja_coleman013.pdf

[4] http://www.shortrotationcrops.org/PDFs/2002Mtg/37Mirckv2.pdf

[5] http://epppublications.com/Documents/11-3-3.pdf

[6] http://www.shortrotationcrops.org/PDFs/2003Mtg/27-Isebrands.pdf

:: 'LENGTH OF THE ROTATION PERIOD'-PARAMETER

Rotation length also affects nutrient removal, and it has been shown that the smaller the tree the higher the share of nutrients in bark and fine branches. In longer rotation periods specific nutrient removal of N, P, K, Ca and Mg is reduced.

:: SOIL DEPLETION OF ORGANIC CARBON

The soil depletion of organic carbon (C_{org}) is an agricultural problem worldwide. Therefore, one major aim of SRF is improving recirculation of mineral nutrients and enrichment of the soil with C_{org}. The increase of C_{org} in soil regions by the roots has positive effects on greenhouse gas (GHG) emission reduction through binding carbon temporarily. Furthermore, an enrichment of C_{org} in the soil increases water storage capacity and can reduce water run-off after heavy rain events, thus, minimizing the risk of flooding.

There are two ways to recirculate C_{org} to the fields. An easy and cost effective way is the collection and distribution of organic waste. Another possibility is application of sludge sourced from waste water plants, but this method is more cost intensive as it needs a central facility to treat the waste water.

:: MATURE AND GREEN COMPOST

Another method to bring C_{org} back to the sites is by using mature or green compost. It is necessary to distinguish between both types of compost as there are specific differences which need to be taken into account. It has been shown that only mature compost is able to suppress weed germination properly. Contrarily, green compost can bring seeds to the field which then germinate and cause weed problems. Seeds present in mature compost are already dead and therefore not able to germinate.

In the case of economic goals (high turnover) the composting area has to be cleaned as quickly as possible, which leads to a higher share of green compost rather than mature compost because it is much faster to produce. This is in spite of the evident advantages of using mature compost. When collecting green waste from urban centres, if the 'collection discipline' of citizens is good the content of noxious substances will be low and these materials can be directly applied to the fields.

:: MINIMIZING CARBON LOSS

To minimize Corg loss, the opening of the soil should be kept to a minimum. This is a strong argument for long rotation periods.

:: RECIRCULATION THE ASH FROM SHORT ROTATION FORESTRY

Recirculating nutrients via ash from wood has a long tradition. Non-fugitive elements like Si, Ca, Mg, K, P, Cu, Zn and Cd can be recirculated into the soil. Limestone is the main component of ash derived from willow and poplar. Potassium is also an important constituent of the ash. The K2O content differs depending on the age of the trees (lower content in old trees) site and the climatic conditions during growth of trees. The content of P is usually low, ranging from 0.05 to 0.15% (Lewis, 2007).

:: TYPES OF ASH FROM BIOMASS PLANTS

There are new kinds of biomass plants with boilers and flue gas purification that produce two kinds of ash:

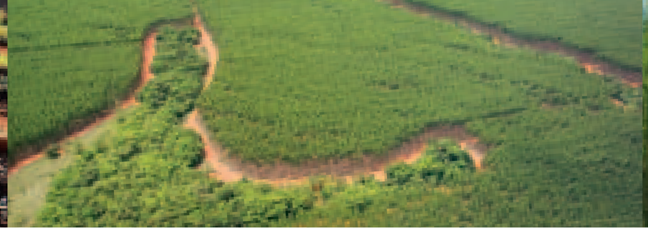
- gross ash with a low content of heavy metals, which can be applied to fields if regional and national legal requirements are met
- fine particles (filtering of flue gas) which have less volume and mass but a high content of heavy metals

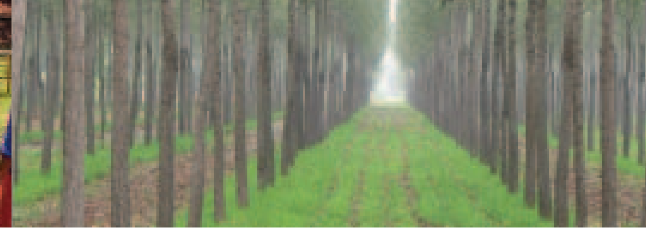
:: RECYCLING RATE AND WATER SOLUBILITY

An optimal recycling rate is achieved when most of the main nutrients are recirculated. The water solubility of Ca, Mg and K standard values are 50%, whereas solubility of phosphorus is about 10%. Although, Van Lerberghe and Balleux (2001) mention that natural phosphate is not soluble in water.

:: NITROGEN

The demand for nitrogen by poplar and willow is relatively low. There are different reasons for the low demand like recirculation of nitrogen by mulching of leaves and weeds. Furthermore, nitrogen can be produced by metabolisms occurring in root penetrated parts of the top soil via symbiotic fixations; this is the case for *Alder* and *Robinia* (Lewis, 2007).

KENYA

To reclaim the land at the end of a SRF or after harvesting, the debris produced during the harvesting process are left on the site and put into rows, before incorporating with the soil during subsequent land preparation for agriculture crops. Fires are discouraged at such sites although farmers find it very easy and convenient to use fire to clear the land. The site is cultivated with both grains and legumes to restore the soil fertility and plant residues are left on-site. Cultivation of such sites with leguminous plants for two or three seasons helps to restore the soil fertility.

After harvesting of trees, the debris is put into rows and crops are planted inbetween them. The debris then decomposes on site and with time turns into humus. The crop residues after harvest are left lying on-site where livestock are introduced to feed on them. Through their movement, the animals soften the ground and scatter the vegetation residues whilst also dropping dung on site.

By incorporating plant and crop residues into the soil, soil properties are improved by making it more porous and, thus, increase water holding capacity. These activities are done manually rather than mechanically.

During the vegetation period of trees, nutrients are rarely applied to increase their growth. However, where trees are grown together with agricultural crops, fertilizers and/or manure are added for the sake of the crops, thereby, also benefiting the trees. In public forests no fertilizers are added except from the potting soil mixture that is brought together with the seedlings from the nurseries to improve the soil nutrient status.

Manure is normally added at the planting time of agricultural crops which is just before either the short or long rains; where manure is used for seedlings, it is mixed with top soil before returning into the planting pit (Figure 18). Fertilizers, if used, are introduced at the planting time, but are also used by some farmers during the agricultural crop season as top dressing or foliar feed. These are less beneficial to the trees as they are placed close to the base of the agricultural crops and away from the tree seedlings. Other means of nutrient addition include mulching whereby the mulch decomposes with time and releases some plant nutrients.

Although fertilizers are rarely used for boosting tree growth on public and private lands, they may occasionally be used at the nursery level. Fertilizers are here added to soil that is considered to be deficient in vital plant nutrients. The targeted elements are Nitrogen, Phosphorus and Potassium (NPK). Additionally, animal manure is added to the soil to improve the carbon content of the soil. Where manure is not readily available, top soil collected from a natural forest is used to provide the organic matter.

The use of limestone to buffer acidic soil is not very common in Kenya. Where acidic soils exist, adapted tree species are used instead of trying to manipulate the soil e.g. *Markhamia lutea, Calliandra calothyrus, Cassia siamea and Sesbania sesban.*

Soil analysis for nutrient content is not done mainly because of the costs of laboratory requirements. So far it has not been considered as important to determine such accurate nutrient status of the soil prior to selection of species to plant. However, farmers' observations of crop growth and the plentifulness and dominance of a particular weed or grass may indicate which nutrients are deficient. Generally, dark-coloured soils are assumed to be fertile and high in soil organic matter. Soils with a loamy texture are assumed to be more fertile than sandy soils. Plantations whose trees are harvested together with their branches, and the bark and foliage used for animal feeds are assumed to suffer from heavy losses of nutrients.

Figure 18: Tools and compost manure pit.
Source: Genevieve Lamond, 2011.

INDIA

Trees are known to capture atmospheric nutrients available in rain and dust with their widespread canopy and nutrients derived from weathering rock minerals in B or C horizon of the soil by drawing them up with their roots. SRF species tend to require higher levels of nutrients for their optimum growth and these nutrients are then exported from the system on harvesting, thus, depleting the inherited nutrient pool. These losses are managed by applying external inputs in addition to inputs from litter shedding, down profile pumping and also by including leguminous and non-leguminous nitrogen fixing trees in a plantation.

Salt affected soils are reclaimed through the addition of gypsum, whereas acidic soils are reclaimed through lime addition. Breaking up of calcium/magnesium carbonate hard-pan crusts is done mechanically to facilitate deep penetration of roots to extract nutrition and moisture.

Appropriate time of application of fertilizers is very important. In general, mobile nutrient salts e.g., nitrate, chloride and sulphate should be applied at the time of peak requirement so they are easily available for the plants. Immobile nutrients like phosphorus may be applied at the time of planting or before planting e.g., as basal dressing. It is not advisable to apply total fertilizer requirements in one dose; it should be distributed 2 to 3 times over a year to avoid losses.

In general, trees are not fertilized exclusively but the recommended dosage for sole crops is increased by 25 to 50% so that nutrients beyond the crop root zone are available to the trees. Nutrients for trees are applied as per requirements and after evalutating the soil for any deficiencies. Nitrogen and phosphorus are commonly applied, whereas, other nutrients are applied as and when required. Additionally, carbon enrichment is provided via application of green debris.

Nutrient export is a critical concern in SRF plantations on farmers' fields. Normally, nutrient removal through frequent harvesting exceeds the input. Although retaining fallen leaves and small twigs on the soil during the growth period and harvesting may be worthwhile to lower nutrient removal from the site, in energy deficient countries this is not always an option and almost all biomass is removed from the system to meet various needs.

CHINA

In China, the following measures are performed in order to maintain and/or recover the fertility of the soil:

- + Rotate crops according to the local situation to maintain a balance of nutrients and moisture
- + Use organic manures and fertilizer to improve the organic content
- + Deep ploughing in combination with no-tillage-straw application to promote the formation of good physical structure of soil and increase ventilation, perviousness and nutrient holding capacity
- + Adjust the proportion of the land use held under agriculture, forestry and animal husbandry and improve the fertility and yields

Among these, rotation of the crop and fertilization on small areas is always done manually. The other measures are performed with the help of machinery.

Generally, additional fertilizers are not needed as straw ash is commonly used as fertilizer. The burn-off rate can reach to 96% where the remaining 4% are rich in calcium, magnesium, phosphorus and potassium that can be made into good inorganic fertilizers.

In China, certain measures are taken in order to minimize the negative effects of soil opening. Key techniques are as follows:

- + Farmyard manure is used to change soil structure. Soil is covered with farmyard manure in order to soften it. Farmyard manure can increase organic matter and humus compounds in the soil
- + Changing from scarification to minimum ploughing and then no-tillage. This method is performed based on the soil condition

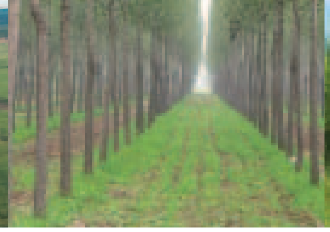
Land in the southern part of China is mostly made up of acidic soils, and limestone is usually used for neutralizing purposes. Limestone enriches the soil with aluminum, iron, and mangan and eliminates the poisons. It is beneficial for encouraging more micro-organisms which enhance decomposing processes and enrich the soil as a result.

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Research about impacts of sludge application or the fermentation rests of biogas plants in SRC stands, research about compost application in combination with the recirculation of ash from energy utilized wood.
2. Modeling nutrient compartments and export via cutting to identify needs for fertilization.
3. Quantification of soil changes during conversion from agricultural to SRF. Options for optimal carbon sequestration in soil.
4. Further work is required to create long-term predictive remediation models, full environmental impact assessments, a complete life-cycle analysis and economic analyses for a wide range of landfill scenarios (Jones *et al.*, 2006).





3.9 Risks

EUROPE

When practicing SRF and/or agroforestry, there will always be certain risk factors which may endanger the productivity of such systems. Those risk factors can be of a physical and/or biological quality.

:: PHYSICAL RISKS

Climate and weather are major physical factors that can affect plantations in numerous ways. Wind, snow and drought are just a few of the challenges that can face a plantation. The best adapted species against wind breaking are those with a deep root system. In forestry, early cleaning and thinning can support the stability of the stand. This treatment is positive for the height-diameter-proportion (Kramer and Akça, 1995). A small h/d-proportion is correlated with a stabilized stand. Regarding SRF in the BENWOOD project countries, the risk of windbreak is relatively low. However, risk of damage due to wind also depends on the genetic material used and age of the trees. Young trees and short rotations deliver elastic trees which can easily cope with extreme wind situations. Other aspects that influence how prone trees will be to windbreak are the size of the leaves and the morphology of the landscape.

Besides high wind and severe storm events, sticky and heavy snow also has the potential to endanger plantations, particularly if it comes earlier in the year than usual. Evergreen trees like pine are highly susceptible to breakage of stems and branches due to snow. Snow induced risks are even higher when trees are infested with climbing weeds like *Clematis*. Another risk factor is frost that occurs in periods of active growth (e.g. late springtime) which can reduce the growth of plantations. These risks can be minimized by choosing species with late bud burst, or a mixture of species with different times of bud burst may be beneficial.

Dry periods harbour risk potential as well. In Europe, likelihood of extended dry periods increases with continental climate conditions. In Germany, for example, northern States like Schleswig-Holstein and Lower Saxony are exposed to Atlantic climate conditions where extended dry periods are rare, whereas the state of Brandenburg is exposed to continental climate conditions characterized by a frequent occurrence of dry periods (Figure 19). Besides water shortage, dry periods lead to higher risk of wildfires; this is especially prevalent in the Mediterranean regions. Measures to prevent fire can be simple fire-lines which are rectangular to the dominant wind-direction. Planting relatively fire resistant trees is also a good strategy for reducing potential damage to a SRF plantation. Another prevention method is removal of herbaceous and bushy vegetation from the plantation on a regular basis.

:: BIOLOGICAL RISKS

Biological risks can be mainly divided into risks posed by pests, diseases, and mammals. The most effective precaution is the planting of species and varieties that are well adapted to the climatic, geographical and edaphic conditions. Furthermore, national guidelines for planting SRF species should be regarded in order to develop a fast growing and viable plantation.

:: PESTS AND DISEASES

There are specific, adapted fungi and insects for each tree species. Under normal conditions the trees tolerate a 'normal' infestation with diseases and pests and are still able to produce despite being infested. However, a huge problem is the immigration of new pests and diseases into indigenous ecosystems. In Europe, the fungus *Ceratocystis* killed nearly all old elms in the past and still infects every elm which reaches a specific diameter. Leaf rust and bacterial diseases are also an issue, particulary in Sweden (Best Practices, 2011).

In Austria, damage is often caused by *Cryptodiaporthe populea* (Trinkaus, 1998) and rust fungus (*Melampsora spec.*). The rust fungus affects the leaves and causes reduced photosynthesis and earlier leaf fall in autumn. In some cases it causes death of entire plantations, particularly when a susceptible clone has been planted. Because of economic as well as ecological reasons fungicides are not usually applied or allowed in Austria, even in the case of a heavy infestation.

Leaf beetles occur in Austria within nearly all SRC stands of poplar and willow (e.g. *Chrysomela spec.*). Some insect pests that are capable of mass propagation and causing calamities in production are: willow beetle (*Phratora vitellinae* and *Phratora vulgatissima*), leather jackets (*Tipulidae spec.* larvae), and giant willow aphids (*Tuberolachnus salignus* and *Pterocomma salicis*) (BioMatNet, 2004)).

Figure 19: Damage caused by drought. Source: Landwirtschaftliches Technologiezentrum Augustenberg, 2010.

:: MAMMALS

Mammals that are most damaging to trees in Europe are deer, voles, hares and rabbits. The damage caused by deer is important in most of the European countries except the U.K. In the U.K. rabbits and hares are more damaging to plantations; this is because there are bigger populations of these animals than that of deer. The importance of mammals and the risk they pose to plantations differs amongst European countries. In Austria, Poland and Germany it is a very important issue (although varying across the regions), whilst in Italy it is of little importance.

The tree species, spacing of the trees and the local deer density are the main parameters influencing the attractiveness of plantations to mammals. Damages due to mammals can be divided into browsing, fraying, debarking, bark gnawing (rabbits, mice) and felling (*Castor fiber*):

BROWSING

The height of browsing mainly depends on season, topography and animal species. Generally, deer browse up to 180 cm whereas rabbits and hares browse up to a height of 70 cm. Browsing height increases in wintertime due to the snow layer. The browsing animals will feed on the buds, leaves, needles, shoots and parts of woody or bushy shoots.

FRAYING

Fraying damage is caused by antle-wearing male ruminants. It is season dependant and occurs when deers like roe, red, sika or fallow deers mark their territories in spring and in rutting season. Male ruminants do it to rub off the skin during antle growth. Fraying in the rutting season makes deep marks on the stem and often the bark is stripped off around the stem and twigs are broken (Figure 20).

DEBARKING

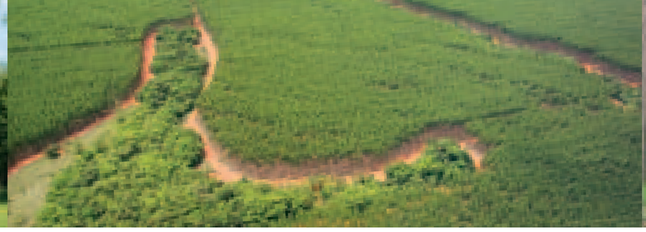
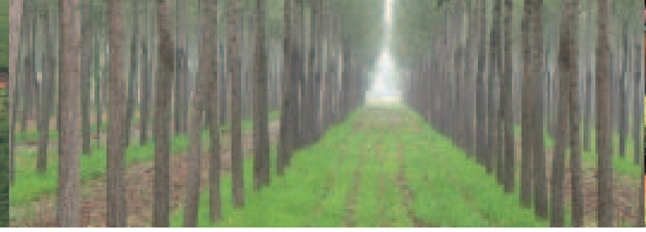
Debarking in summer and wintertime is caused when mammals feed on the trees. During the wintertime, clearly visible marks of teeth are shown after debarking activities. However, damage caused in the summertime is more severe as stripping off the bark is easier and, therefore, more intense. Red and sika deer (*Cervus elaphus* and *Cervus nippon*) are the species with the highest affection for debarking followed by moose (*Alces alces*), moufflon (*Ovis ammon musimon*) and fallow deer (*Dama dama*).

BARK GNAWING

Rabbits and hares (*Oryctolagus cuniculus* and *Lepus europaeus*) gnaw the bark for feeding and marking purposes. Plants with a diameter of 5 to 6 cm are the main affected trees. Besides rabbits and hares, damage due to bark gnawing may also be caused by mice and voles. In Germany, long-tail voles are listed in the Federal Ordinance on the Protection of Species, so countermeasures against any damage caused are not allowed if death-inducing. These voles feed on seeds and germ buds (NW-FVA, 2010). Short-tailed voles are more dangerous to afforestations; these are the brown vole (*Microtus agrestis*), the bank vole (*Clethriominus glareolus*), the common vole (*Microtus arvalis*) and the water vole (*Arvicola terrestries*). The most dangerous species is the water vole as they feed on the roots of the trees; damage happens mostly in autumn when there is no frost in the soil.

FELLING

In Germany the special protected beaver (*Castor fiber*) causes significant losses of SRF trees (Müller and Helbig, 2009). As the beaver is protected through certain FFH-guidelines, populations and individual animals cannot be engaged.

:: MEASURES AGAINST ANIMALS

Measures against deer, hares, rabbits and beaver can be fencing, single protection, careful site selection and hunting (except the protected species). In the case of fencing there are different requirements depending on animal species. For roe deer, smaller fences up to 150 cm are useful (in areas with low snow cover in winter), whereas, fences against fallow and red deer should be up to 180 cm in height. For rabbits, it is important that the diameter of the fence windows is smaller than 31 mm. For hares, the diameter has to be 50 mm and for red deer and fallow deer the diameter can be up to 15 cm. The fences must be fixed onto the ground or even buried in the ground (usually up to 30 cm). This ensures that no wild boars will dig up the fence and create potential entries for other animals.

:: COUNTERMEASURES AGAINST PESTS AND DISEASES

There are certain methods which can be applied to combat pests and diseases pre- and post-infection. When the first symptoms appear, the causative agents need to be determined as soon as possible.

Figure 20: Fraying damage. Source: Christian Siebert, 2010.

SILVICULTURAL METHODS

It is recommended to plant healthy and hardened plants of mixed species in rows, groups or wide stripes. Spacing is important to consider as planting trees too densely can cause high competition pressure which weakens the plants. Another reason for wider spacing between trees is to avoid contamination via contact. However, in the case of an obvious infection, infested trees have to be removed from the plantation in order to prevent spreading of pathogens.

PHYSICAL METHODS

Physical methods may be the trapping and destroying of parasites, as well as destruction of infected trees. If a tree is infected but can be treated by cutting off the infected part, it should be treated using hygienic measures, e.g. waxing of wounded parts. This prevents the tree from re-infection and is beneficial for wound healing purposes.

BIOLOGICAL METHODS

Pest control can also be performed using biological antagonists, e.g. the release of the lady bird to reduce greenfly populations, or the preservation of bird nesting areas to limit the proliferation of caterpillars and larvae. In the U.K., development of non-chemical approaches has been an issue but until today no satisfying solution has been reached.

For combating different forms of rust, non-chemical approaches based on cultivated mixtures and biological control are well regarded. Currently, self-sustaining biological methods seem to be superior when compared to chemical fungicides.

CHEMICAL METHODS

In the case of controlling caterpillars and larvae in Germany, the main substances are Karate® and Fasttac®. They are proven in addition to the ordinance about 'phytosanitary substances and phytosanitary equipment' (PflSchMGV, 1987).


KENYA

Insect pests and diseases are the main risks to SRF plantations in Kenya. Particularly when forests are established as monocultures they are more at risk of suffering serious damage when attacked by insect pests. There are other risks to successful SRF production, including adverse climatic conditions and water resource depletion. Improved planting material is not always available, proper management practices are not always followed and protection against adverse conditions not taken. Many of the commonly used SRF tree species are exotics and, therefore, may not be as well adapted to local conditions as indigenous species.

Specific SRF tree species' pests and diseases for Kenya (Source: Dr. James Kimondo, pers. comm., 2010):

+ *Cupressus lusitanica* – Cypress aphid
+ *Eucalyptus species* – Blue gum Chalcid
+ *Pinus radiate* – Dothistroma blight
+ *Grevillea robusta* – Stem canker
+ *Casuarina equisetifolia* – Bark blister
+ *Leucaena leucocephala* – Leucaena psyllid

Through the control of the importation of germplasm into the country either in form of seed, vegetative material, or wood products from neighbouring countries, the emergence of risks is prevented and/or reduced. Phytosanitary conditions are enforced by passing all imported material through the quarantine station. Other control measures are the application of best management practices (especially land preperation), planting trees according to their local suitability and adaptability, maintaining broad genetic base and using biological control methods.

INDIA

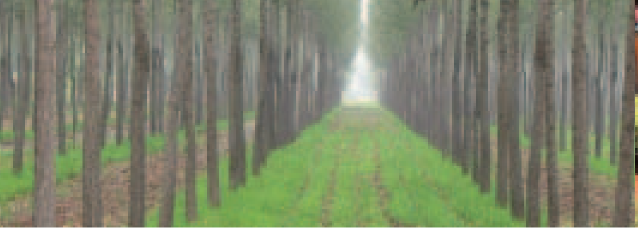
The most common risks for successful SRF plantations in India are physiological disorders, adverse climatic conditions, pest and diseases of trees and water resource depletion. Many problems are also caused by humans, in the event of planting material not always being available, proper cultivation practices not followed and mitigation actions against adverse conditions are not taken.

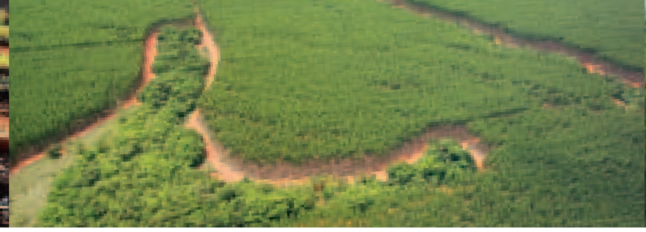
Insect pests exert substantial losses in terms of growth and productivity in plantations and stored timber. In order to reduce potential risk factors, the following aspects should be taken into account:

+ Use good quality planting stock
+ Apply recommended cultivation practices
+ Maintain proper drainage facilities
+ Plant trees according to their site adaptability
+ Maintain broad genetic base
+ Sanitation measures adhered to

In order to protect plantations against pests and diseases, a range of silvicultural, biological, mechanical and chemical control approaches are followed. Sanitation, eradication, isolation trenches, chemical control, improvement of the site and tolerant SRF species selection are common practices and are applied depending on their cost effectiveness.

Figure 21: Damages caused by insects. Source: PAU, 2010.





CHINA

The risks that may affect and influence SRF plantations in China are mainly pests, diseases, animals and meteorological calamities such as windstorms, snow and floods. In poplar, for example, the main drivers of disease and insect pest infestations are:

+ Areas of SRF expanding but consisting of single species or limited mixes and natural ecological control being low in ability
+ Ecological environment deterioration: due to the recent phenomenon of warm winters, some plant diseases and insect pests can have a greater and more prolonged impact
+ Extended application of chemical treatments which leads to pests and pathogens developing drug resistance, thus, increasing the difficulty of prevention and cure solutions
+ The quality of the poplar gene pool being degraded due to a lack of diversity
+ Administrative staff not being fully aware about the importance and arduousness of applying prevention and cure methods to decrease incidence of diseases and pests

The most commonly applied 'prevention and cure' methods in China are:

+ Increasing the span of tree varieties
+ Arranging the structure of the trees according to age
+ Reducing the afforestated area appropriately
+ Biological control
+ Chemical control

In China, nematodiasis in pine populations has been a major concern since a devastating outbreak in 1982. Over a period of 10 years from 1982, the nematodiasis caused the death of 1.4 million pines and, as a result of this, a 50.000 m^3 timber loss. Because of this, several 'prevention and cure' techniques and methods were developed and are applied regularly. Generally, it is recommended to create mixed forest, pay close attention to nursery stock, and develop an integrated defence strategy.

Recommendations are to:

+ Remove seriously injured trees
+ Strengthen management of water application
+ Set up networks for monitoring symptoms and outbreaks (levels: county, township, village)
+ Apply integrated biological, physical and chemical control for effective results

RISKS IN AGROFORESTRY: GERMANY

Agroforestry systems are normally less exposed to risk than monocultural production systems concerning site conditions, pests, diseases or complete failure. Risks should always be considered in light of alternative production systems and contexts. For example, higher water consumption of a planted tree species may be a hazard when there is high risk of drought events, but on the other hand it may have positive impacts concerning water infiltration during heavy rain events. In Germany, some risks are: soil compression during cultivation processes; herbicide usage; introducing foreign or genetically modified species; loss of biodiversity or C sequestration depending on the previous land use (Lamersdorf[7]). However, most of these risks are able to be mitigated via proper management.

Agroforestry and SRF concepts in Germany are nowadays mainly driven by economy and the related sustainable energy discussions. As the biomass demand for energy rises, utilization concepts of woody biomass get adapted. In general, forestry resources based on sustainable production concepts for high quality timber need relatively long rotation cycles. This causes a limited flexibility for providing suitable biomass without losing high income possibilities in the future and detrimentally disturbing forest ecosystems. Agroforestry offers the possibility for production in the short-term and the long-term by combining complementary components for a sustainable system of production.

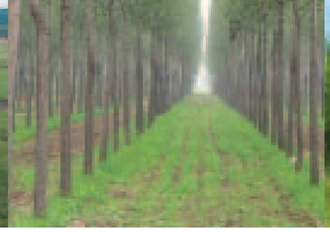
FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Research on biological control methods of specific diseases and pests and investigation of pest dispersal/population dynamics and forecasting. The U.K. suggests further monitoring of pathotypes and populations especially of rust fungi (biomatnet.org, 2010).
2. Genetic outcrossing and optimisation especially for willow and a careful selection of genetic material. Research on a broader genetic base and improved germplasm. Careful assessment if non-native species are to be introduced because of possible new pests and diseases.
3. Research on companion planting (e.g. understorey or boundary plants to harbour or repel predator species) to avoid the need for drastic measures taken against pests.

[7] http://www.bfn.de/fileadmin/MDB/documents/ina/vortraege/2008-09-04-Lamersdorf_KUP-AFS.pdf





3.10 Interaction with other Ecosystems

EUROPE

:: EFFECTS OF SRF/AGROFORESTRY (AF) ON FLORA AND FAUNA AND LANDSCAPE FUNCTIONS

The title of this chapter, 'interactions with other ecosystems', already indicates that SRF/AF systems can be characterized as individual 'ecosystems'. They certainly interact during their life times with the surrounding environment, whether with other ecosystems or within human frameworks (Pretzsch, 2010; Bell *et al.* 2001). Another subdivision of the interaction between ecosystems differentiates between the abiotic and biotic interactions as well as qualitative aspects from a human point of view regarding landscape functions (Figure 22). The interaction of SRF/AF with ecosystems can be measured in terms of its impact on local climate, soil ecology, plant and animal diversity, landscape diversity and ecology, regional water household and impact on wind speed and the effects on erosion (impact assessment from different kinds of management see BEST Project[8]).

The level of impact that a SRF/AF system has will depend largely on the land use being replaced. If degraded or crop lands are replaced by SRF there will usually be a positive effect. This positive effect is mainly due to a reduced application of herbicides and pesticides. The reduction enhances the habitat quality for animals.

The impact of SRF/AF can be enhanced positively by having mixed species/clones and diverse planting arrangements and the following points can be considered (Schulz *et al.*, 2010):

+ Plantation diversity: different rotation periods; different tree species; different ages
+ Diversity of structures between stands: balk structures; inner borders; conservation of glades or derelict land areas; special structures, e.g. stone or deadwood piles
+ Diversity of structures along the plantation borders and other areas: hedges; balk structures; solitary trees; special structures (as above)

Studies in Sweden, Germany and Italy indicate that cultivation of SRF often causes an increase in biodiversity (Alasia, 2010; NABU, 2008). Regarding levels of biodiversity there is a list starting with willow at the top, followed by poplar, robinia and ailanthus (Schulz *et al.*, 2010). Reports from Austria and Poland state that SRF has positive effects on populations of honey bees and wild bees (Lewis *et al.*, 2010), as well as small mammals evidenced by raptorial birds being able to catch more mice (Best Practices, 2011).

Busch (2010) listed potential influences of SRF/agroforestry on landscape functions after having researched a methodology for assessing the influence of SRF on landscape functions through the usage of Geo Information Systems in Lower Saxony (Germany). Schmidt and Glaser (2009) and Busch (2010) mentioned positive effects like reduced wind velocity; reduced evaporation; reduction of soil erosion; balancing impacts regarding air moisture; increased water retention, and retention of soluble nutrients and pollutants.

Although there can be many positive impacts, admittedly there are also some evident trade-offs. Schmidt and Glaser (2009) demonstrate the conflicts between nature conservation and SRF, some of which are:

+ The endangering and displacement of open area species
+ Destruction of endangered biotopes
+ Establishment of large monotonous SRF areas
+ Use of invasive species like *Robinia pseudoacacia*
+ Use of genetic tuned material (lacking long term impact assessment)
+ Adverse impact on water household of the landscape
+ Spreading of none autochthon clones

Moreover, Schmidt and Glaser (2009) have developed a decision algorithm to assess agricultural areas according to nature conservation criteria and the impact of SRF on protected areas is assessed in this algorithm.

[8] http://best-forschung.uni-goettingen.de/
http://www.uni-goettingen.de/de/3240.html?cid=3656
http://www.fona.de/de/9251

Figure 22: Interactions of short rotation coppice with other ecosystems. Source: Christian Siebert, 2009.

:: SHORT ROTATION FORESTRY AND AESTHETICS OF THE LANDSCAPE

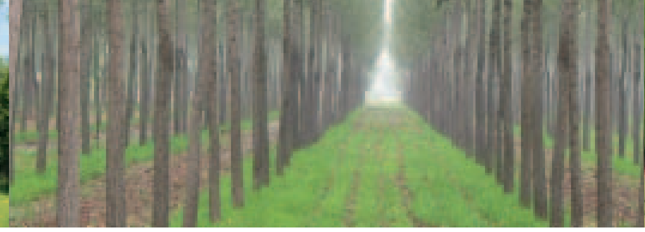
The aesthetic effects of SRF/AF on the landscape are an issue in Germany and in the U.K. There been several studies regarding this topic in Sweden (http://ratingsrc.slu.se) and it appears that opinions and attitudes about aesthetics of SRF plantations change with time and are also dependant on the size of area covered with trees.

In the U.K., a thorough consultation has to take place in order to gain approval that the new culture fits within the landscape and that there are no conflicts with archeological interests (Sinclair and Lamond, 2010).

:: WIND SHELTERBELT

A valuable ecological aspect of SRF is that the trees have got the potential to protect against wind and erosion (Hofmann and Siebert, 2010) which is the main purpose of shelterbelts worldwide (Best Practice, 2011). In 1930, shelterbelts of poplar were planted widely in Austria, but they have not been maintained up until today. Those poplar populations have now reached an age where they are in danger of breaking and are now being felled but unfortunately replacement activities are not taking place to ensure sustainability of the system.

Shelterbelts can be realized as a form of SRF. When they are managed with this purpose they can deliver wood for local populations. This is an important aspect for Non-Annex I countries where wood is in high demand. To allocate wood supply and shelter function it is necessary to design/develop harvesting cycles which ensures that both functions are considered and met.



KENYA INDIA CHINA BRAZIL

KENYA

In Kenya, SRF and agroforestry systems provide positive effects on the surrounding environment via reclamation of degraded soils, employment generation, environmental amelioration, and socio-economic benefits. However, those effects highly depend on the species planted and the context in which they are situated. The effects of SRF/agroforestry systems on the livelihood of the farmer and direct impact on the environment in terms of soil and water conservation are more important than landscape aesthetic issues. Trees are primarily cultivated for the benefits that they can give in terms of utility for domestic consumption, on-farm soil and water conservation, and monetary income from the timber and firewood. The trees can be seen to provide multiple benefits rather than being exclusively for just one product, service function or use.

INDIA

SRF/agroforestry systems positively influence the reclamation of degraded soil, environmental amelioration and socio-economic issues by generating employment and production for high demand firewood/timber markets. Furthermore, such systems can act as a replacement for certain less stable systems. Aesthetic issues play a very little role in India. Agroforestry systems play additional roles of honey bee rearing, pharmaceuticals and lac culture.

Figure 23: Termites. Source: Genevieve Lamond, 2011.

Figure 24: Bee rearing under poplar. Source: PAU, 2006.

CHINA

The influence of SRF/agroforestry systems can be shown by the following example based in the autonomous county of Duerbote Mongolia, Heilongjiang province in Northwest China. In the livestock breeding station of Duerbote Mongolia, there is a mode of planting sparse *Pinus sylvestris* forest on meadows and pastures in order to raise chickens under the trees. The grass can be used as the main feed source for chickens which is beneficial in terms of saving feed and production costs. Furthermore, the grass can also be used as a feed source for cattle and sheep. Besides animal husbandry, plantations provide a habitat for wild animals as well. This is beneficial, as many wild animals are predators and feed on rats which are viewed as pests in this region.

Additionally, SRF/agroforestry system can prevent the loss of soil and water, reduce wind velocity and water evaporation, moderate air humidity and soil temperature, and improve soil structure within the forest in order to provide a good environmental condition for survival and growth of grass; this feeds back into the system either as livestock manure or mulch material.

BRAZIL

The cultivation of *Eucalyptus spp.* in Brazil has developed well over the years and the Brazilian forestry sector has adopted the use of forest mosaic, also known as ecological or biological corridors. The forest mosaic is the practice of planting forests in native forest areas to create a corridor between pieces of land with natural forest. This allows the transit of wildlife and increases available habitat. Local studies have shown that there is a higher flow of wildlife in areas with mosaics of 50 to 100 ha compared to non-mosaic practices.

The visual impacts caused by large-scale plantations, even though they are not considered a relevant problem in Brazil, are minimized by mosaic planting practices. The same can be applied to agroforestry practices.

Some companies that own areas of forests give incentives for bee breeding activities within their property limits, as a way to improve the producer's income, although this cannot be considered a common practice in the country.

FIELD OF FURTHER RESEARCH

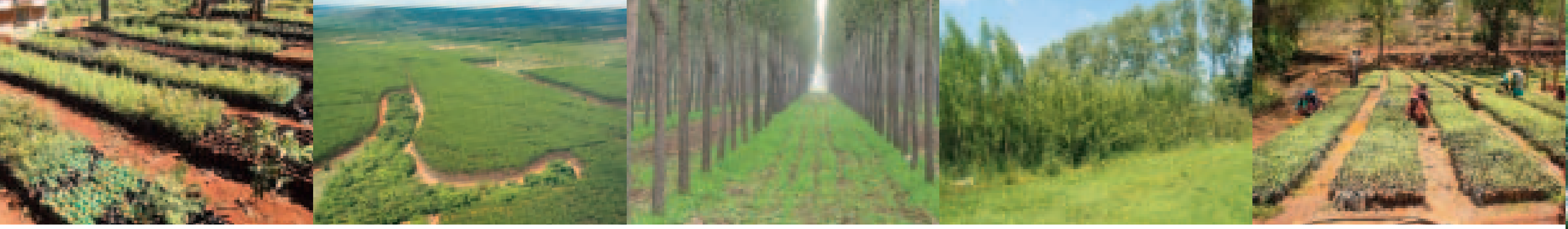
The research questions posed by project partners were very diverse and are differentiated between ecosystem interaction and the human framework.

Ecosystem interaction questions:

1. Impacts on soil ecology, nutrient availability, pools and fertilization, consequences of agroforestry management for nutrient stores and nutrient turnover in soil and phytomass (Marinari *et al.*, 2007; Hölscher, 2001).
2. Carbon storage capacity.
3. Management optimization (Mitchell, 1990; Cotrufo 2005), impacts on the regional water household (groundwater recharge on landscape level).
4. Water infiltration and retention capacity and the effect on flood events.
5. Plant and animal diversity regarding different clones in one plantation (Schulz *et al.*, 2009), as structural element and as composition of the biocoenoses.
6. Interaction between trees and livestock.

Ecosystem interaction within a human framework:

1. How SRF can support (socio-) economic benefit of side uses, e.g. honey production using willow, firewood for local markets.
2. How to measure aesthetics: evaluation of attitudes towards SRF (Bell *et al.*, 2001; Pretzsch, 2010).



3.11 Harvesting

EUROPE

TIME OF HARVEST

In order to prevent severe damage of the plants two phytological periods should be considered for harvesting. The plants have to be lignified and in hibernation which limits the timing of the early harvest. Cutting an 'awake' tree in early spring or summer may lead to death of the tree or reduce its vitality significantly (Hofmann, 1998).

In comparison to the early harvest, late harvest means that the harvest has to be finished before budbreak. A proper time to harvest SRF areas is in the winter and from October to February is the general timing for this (Defra, 2004; Hofmann and Siebert, 2010). However, the optimal harvesting time differs regionally (Defra, 2004). To avoid soil compaction due to heavy machinery the harvest should be done in periods of stable frosts.

The following requirements and aspects should be considered when deciding the right moment for harvesting:

:: TAPPING THE FULL POTENTIAL OF THE GROWTH CURVE

The growth curve shows the relation between time passed since planting or last harvest and dry matter accumulated per hectare. In general, the growth curve is heavily species specific. In poplar, the highest dry matter content is accumulated after a minimum of three years. In black poplar the highest dry matter accumulation is reached after three to five years and in balsam poplar after eight to 12 years (Muhs and Wühlisch, 1990). In contrast, willow accumulates after one up to three years.

:: HEIGHT OF TREES

The height of trees reaches more than 8 m in longer rotation periods of more than four years due to classical harvesting methods.

:: SOLIDITY OF THE SOIL

In order to use heavy machines the soil has to be as hard and as durable as possible (frozen ideally). The requirements for the solidity of the soil depend on the slope and the type of harvesting machine (weight and tire types). However, in most cases the harvesting process occurs without drawing attention to soil conditions and whether they are favourable or unfavourable. Reports from Germany (Hofmann and Siebert, 2010) and the U.K. (Sinclair and Lamond, 2010) showed that there can be drawbacks due to soil compaction, therefore, harvesting and processing techniques should be adapted and applied according to the soil type and condition. It is important that the stumps are not damaged by harvesting as this may reduce the coppicing ability and also increases the risk of mycotic infections.

:: WATER CONTENT

One advantage (better pre-condition) of harvesting in winter is that the moisture content of wood is low at this time which has positive effects on the wood characteristics for good storage (Best Practices, 2011; chapter 3.12: Transport and Storage). Most country reports indicate moisture content between 45 and 60 % is aimed for. The moisture content will vary between different harvesting dates, types of clones and harvesting methods (University of Life Science in Vienna).

:: TIME FLEXIBILITY

Time flexibility for harvest is important for SRF to be competitive on the market. The following parameters have an influence on the flexibility: weather conditions, market price, availability of machines and storage capacities. These factors can make it advisable to delay the harvest for one year after taking into account stem diameter and height of the trees.

HARVESTING METHODOLOGY

The harvesting methodology depends on:

+ Purpose of final product
+ Final stem diameter (different machines can handle stem diameters up to 15 cm)
+ Total area which has to be harvested in the season
+ Availability of machinery

Figure 25: Semi manual harvesting with a chain saw. Source: Plantar, 2008.

In *Annex I countries* the following strategies have been developed or emerged:

+ Focus on wood chips
+ Use of large harvesting agriculture machines equipped with a front mounted machine tree mower
+ Small diameters of trees due to the mowing harvesting technique
+ Focus on rotation periods of 2 to 3 years
+ Use of fertilizers and herbicides
+ High yield clones from specialized clone breeders

In Austria there were initial drawbacks to some of the abovementioned choices. At the moment there is a discussion about how to change or correct the 'mow-and-chip' strategy. One motto is 'broaden the perspective and strive for approaches beyond merely producing chips on the field' (Best Practices, 2011). According to the 'broaden the perspective' motto, the University of Life Science in Vienna implemented a 5 year rotation in Romania which will use a harvester.

There are different options for harvesting an SRF/AF plantation:

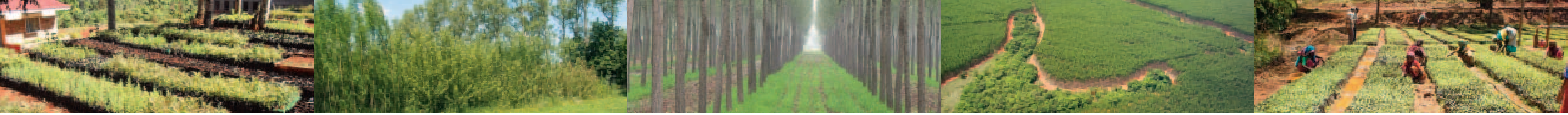
:: MANUAL AND SEMI-MANUAL HARVESTING

These harvesting methods are not so commonly used in highly mechanized European countries, but are present to a small degree in Poland in SRF systems and in the U.K. in agroforestry systems (Siebert *et al.*, 2010). During semi-manual harvesting a farmer uses a chainsaw for felling (Figure 25). After the felling, further machines can be used for transportation or chipping. Some machinery can be used that the farmer already has for his farming activities which saves costs. However, this method is only possible or recommended for stem diameters up to 15 to 20 cm (Hofmann and Siebert, 2010).

For manual and semi-manual harvesting there are two reasons for chipping on the fields or the field´s margin. On the one hand the transport of trees with small diameters is more space consuming than transport of chipped wood, and on the other hand the customer usually needs the chippings delivered to specification rather than on delivery.

There are different possibilities of chipping on the fields. One is the use of small chippers on the field (e.g. Poland, Dubas, 2010) and/or at the field´s margin. The transport of the whole trees from field to the field margins can be done by forwarders.

An advantage of manual and semi-manual harvesting is that farmers can carry out the harvesting by themselves and/or with the help of the family and neighbours. Consequently, no SRF harvesting service companies are needed and the investment costs can be relatively low. It is possible to use a wheel loader to concentrate the trees in order to make it easier to feed a mobile chipper. This procedure gives farmers the possibility to try out SRF without major financial consequences due to the use of specialized machinery and, compared to fully mechanized harvesting methods, the stem diameter does not play a major role.



Germany, Sweden and Italy are countries with high national minimum wages for manual labour which actually makes manual harvesting too cost intensive in these areas: there are high costs with low output per hour. Because of this, harvesting is mainly done fully mechanized in these countries (Best Practices, 2011).

The U.K. sees advantages of semi-manual harvesting through higher flexibility especially during wet weather periods. Lower usage of heavy machines will have a lower adverse impact on the soil in these conditions (Sinclair and Lamond, 2010).

In Austria, the harvesting method used depends especially on the size of the area. Small areas are often harvested with a chainsaw in order to avoid high costs of the commitment of heavy machines.

:: FULLY MECHANIZED HARVESTING

Austria, Germany, Italy, Poland, Sweden and the U.K. mainly use this method for harvesting SRF plantations (Siebert *et al.*, 2010). Rotation periods shorter or equal to two years are aiming at chip production. For this purpose, agricultural maize harvesters can be equipped with a special designed header (e.g. salix-header or WoodCut HTM 1500). The chipping is done inside the driving unit (Figure 26). The advantage of a replaceable header is that in summertime the driving unit can be equipped with a maize header for harvesting maize.

However, the use of heavy machinery has proven to have a negative effect on the soil structure and can lead to intense soil compaction, leading to negative effects on crops and trees. This is the case for agriculture as well as forestry. The extent of soil compaction via machinery can be influenced or foreseen through the total static axis load of the vehicle and the driving frequency. The actual pressure exerted on the soil (area averaged pressure is calculated by dividing the axis load by the contact area of the tires). The choice of tires and the gauge pressure influence the impact on the soil.

Figure 26: Fully mechanized harvesting. Source: Christian Siebert, 2010.

The following recommendations relate to fully mechanized harvesting with large chipping machines followed by container pulling tractors:

+ A logistic design which considers the trailer receiving the chips (either pulled or by additional parallel driving tractors or chipping units)
+ Logistical aspects with a focus on transport to the final destination
+ Try to limit the times needed for turning the machines
+ Max. diameter < 12 cm, better < 8 cm to reduce risk of stocking and avoid trees that are too long for machinery to cope with
+ Take care of acute slopes (reduce skidding risk)
+ Usage of armed tires
+ Minimize pressure on soil
+ Wait for frozen or dry soil conditions

The use of fully mechanized harvesters also influences the **planting spacing** from the beginning. Willow is usually planted in twin rows and the distance between the twin rows is adapted to the widths of agricultural machines (0.75 cm). Harvesting with chipping machines needs a container which is pulled by the chipper or a tractor. These aspects have to be considered when deciding spacing between two rows. Spacing is important to avoid driving over stumps which can cause damage to tires and stumps. Two planting patterns are generally used:

+ 'Scandinavian style': 1.5 m between the rows; the chipping machine and the tractor run over the middle of the 0.75 m double row with a double row between them
+ 2.5 m between rows and no double row between the chipper and the tractor

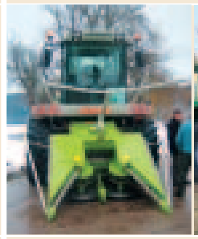
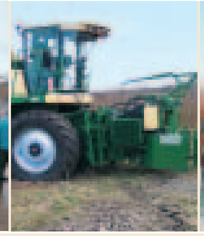
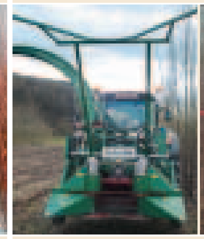
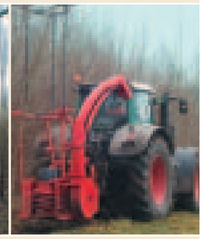
In the case of the 'German shrub mower', the recommended distance between rows is 0.9 to 1.0 m or a row distance greater than 1.5 m.

Other aspects which have to be taken into account are the *avoidance of skidding potential* for machines when planting on slopes and *reserve space* for turning the machine. If the slope is steep the planting rows should not follow the south-north direction (sunlight access), but rather should follow a more vertical path (reduce the risk of skidding on wet soils). The second aspect requires turning space in the form of strips of about 10 m (Lewis, 2007).

:: HIGH PERFORMANCE CHIPPING HARVESTING MACHINES AVAILABLE ON THE MARKET

At the moment there are only a few available harvesting machines in serial production which both fell and chip. One is a header from CLAAS which is sold with the CLAAS driving unit – the main field of application is willow plantations; however, it can also be used for poplar. The other few products in the high performance sector which are comparable to the CLAAS Header are: the *Woodcut* from

Table 11: Comparison of different harvesting headers. Source: KWF, 2011; ATB, 2010; Scholz *et al.*, 2006.

	UNIT	SPECIALIZED CHIPPERS			SHRUB MOWER	
Manufacturer		Claas	Hüttmann	Case New Holland	Schmidt	University of Goettingen
Picture						
Type		header HS-2	header 750	header 130 FB	header	header
Current state of development		small series	prototype	small series	small series	prototype
Weight	kg	1300	2000	2200	2200	1200
Driving unit		Claas-Chipper Jaguar	Krone Chipper BIG XI1	New Holland FR 9000	Convent. Tractor	Convent. Tractor
Power	kW	235	360	606	243	>200
No. of planting rows/working width	– /mm	2/1000	2/1500	2/750	2/1400	1/560
(Distance between twin rows+) Distance between rows	m	0.75+≥1.5	0.75+≥1.5	0.75+≥1.5	0.75+≥1.5	>0.9
Max. diameter of stem	mm	≤80	≤150	≤150	≤120	≤150
Average length of wood chips	mm	5...40	5...30	10...45	–	50...100

HÜTTMANN (Germany) which is a header for driving units from the company KRONE; headers from Italian companies for CLAAS units which are used for harvesting poplar of a 2 year rotation period, and the machine of Case New Holland. Hofmann (2010) calls this method of felling and chipping *'direct chipping'*.

A low-cost approach is the German 'shrub mower' developed by the University of Göttingen. It is smaller than the abovementioned headers and is used on the front of a conventional tractor. The header includes a felling and a chipping unit. The throughput (m^3/h) is smaller than by the chipping units. It is still under development and not available on the market but is presently used in Non-Annex I countries like Namibia and South American countries (Best Practices, 2011). The described machines are shown in the Table 10.

:: CLASSICAL FORESTRY EQUIPMENT FOR INCREASED STEM DIAMETERS AND ROTATION PERIODS

Hofmann (2010) describes the fully mechanized process as a two-phase harvesting system, including the two phases of felling and chipping trees with a diameter greater than 7 cm. But with a more specific view it is a four-step system: first there is the felling, second the pre-concentration, third the skidding and lastly the chipping. This can be done with a harvester or a feller/buncher-system. One main advantage of this system in contrast to the manual harvesting is that there is little risk of injuries for humans/the driver. Another advantage is that the moisture content of the harvested material is generally lower than the direct chipped wood in the one phase system. It can be 20 % lower than the 'fresh' chipped wood (circa. 55 % water content). Chipped material with moisture content of 30-35 % has high storage stability (Hofmann and Siebert, 2010). Even if the main production purpose is stemwood, there are still branches and parts of the tree left for chipping.

:: DEBARKING

For the pulp and paper industry, stems have to be debarked before they are processed in the pulp mill. In Sweden (Dimitriou and Weih, 2010), U.K. (Sinclair and Lamond, 2010), Germany (Hofmann and Siebert, 2010) and Austria (Lewis *et al.*, 2010) it is not a common practice. However, debarking using a special delimber-debarker machine is common in Italy in 5 year rotation systems (Alasia, 2010).

KENYA INDIA CHINA

KENYA

In Kenya, the harvesting is normally carried out by the buyer of the wood material and his workers. The harvesting process can be divided into the cutting process, mainly performed by teams of two people, and transportation, whereby there are people that carry the logs to the trucks and load on to the vehicles; once at the processing point, there are other people to manually down load and arrange the logs ready for processing. As detailed information about the transport process are given in 3.12 Transport and storage, the current chapter focuses on the actual harvesting of the trees.

When facing a large plantation, the main methods of cutting trees are either clearing the whole forest at once at the end of the rotation or cutting the small trees (thinning) during the course of the rotation. The trees are cut manually or semi-manually using mainly saws, axes, machetes, and occasionally chainsaws (commonly called power saws) - which have to be hired and used by skilled operators.

For smallholding systems, trees will be pruned or cut whenever the income need or domestic need calls for the timber/firewood to be harvested; farmers will use fully manual or semi-manual methods, i.e. saw, axe and machete, and/or chainsaw.

One major issue when harvesting plantations is the potential destruction of the soil which is an issue during removal of the cuttings rather than during the actual cutting process. If the trees are skidded down the slope, top soil is loosened and becomes susceptible to erosion. The skidding lines become gullies during rainfall events, washing away top soil and any accumulated organic matter. Wet climatic conditions also increase the risk for workers using chainsaws due to the wet and slippery ground. To lower the destruction of the soil and the roads during transportation, and to avoid increased risk for workers, harvesting is mainly performed in dry seasons.

After cutting, the main stem is cross-cut to a specific length, depending on the size of truck used for transportation and in compliance with certain traffic regulation regarding transportation of heavy and extended loads. The further processing of the trees depends on the intended end use. For trees targeting sawn timber and pulp, cut trees are removed from the forest immediately without any peeling of the bark. The bark remains attached to the off-cut which is sold as a by-product from the mill. The bark may fall off during processing and is then put together with other wood waste. Trees for electricity poles, normally *Eucalyptus species*, are left for 2 to 3 weeks after cutting to reduce the moisture content during which time the bark peels off naturally. In the case of trees for posts and small poles the bark is removed manually with machetes immediately after cutting to enhance their treatment.

INDIA

In India, harvesting is mainly done manually or semi-manually with axes, saws and at a very limited scale chainsaws. During the harvesting process attention is paid not to destroy or negatively affect side-populations as well as the soil. Clones are normally harvested in clear-felling systems which do not affect other plants. Mixed SRF and agroforestry plantation systems are harvested carefully in order not to affect associated plants and trees, which is hard in practice. The soil is also negatively affected due to removal of the roots - the roots are harvested for fuel purposes.

The peeling of the logs is performed manually either at the harvesting site or at an industrial unit. The whole harvesting process including subsequent processes (peeling, loading, etc.) is performed manually and thus, generates sufficient employment. However, due to the manual work the harvesting process can be seen as relatively cost effective with a percentage of 10 to 15% of the whole timber costs.

CHINA

Harvesting in China is mostly carried out manually or semi-manually using chainsaws. The major advantages of this type of harvesting are: easy to operate, flexible, cost efficient, easy applicability and employment generation.

Most plantations are situated in the mountain areas where the use of heavy harvesting machinery is limited. However, the main reason for the huge percentage of manual harvesting is the lack of proper harvesting machinery in China. The machines have to be imported from overseas at a high price and still may not be fully functional for the actual Chinese forestry situation. As mentioned before, one of the major advantages of manual felling of the plantations is the creation of employment.

The harvesting process has direct and indirect effects on the condition of the site in general and the soil in particular and, therefore, on the productivity of following rotations. During the harvesting process, the soil of the site is heavily affected due to road building, ground trampling and transportation via trucks. Cracking and compaction of the soil can cause long lasting damage. When the ground is broken up, the risk of erosion is increased due to the loss of ground vegetation and the exposure of high quality soil layers. These effects are intensified on slopes. Clear-felling rapidly alters the micro-climatic conditions of the site and the soil; the sudden exposure to direct sunlight has major affects on the chemical and physical conditions of the soil. With changing soil physical and chemical conditions there are resultant impacts on micro-organisms and nutrient availability etc. Therefore, the harvesting process needs to be performed carefully and sustainably in order to guarantee sufficient productivity for the next rotation.

Figure 27: Fully mechanized harvesting. Source: Plantar, 2008.

In China, the percentage of debarking is relatively low; whether debarking happens or not will depend on the tree species and intended end use. If the bark of trees is removed, then it is done manually using spuds, choppers and reaping hoods. Certain tree species are peeled in summer on the standing tree and harvested in autumn, whereas, other trees are debarked after harvesting.

BRAZIL

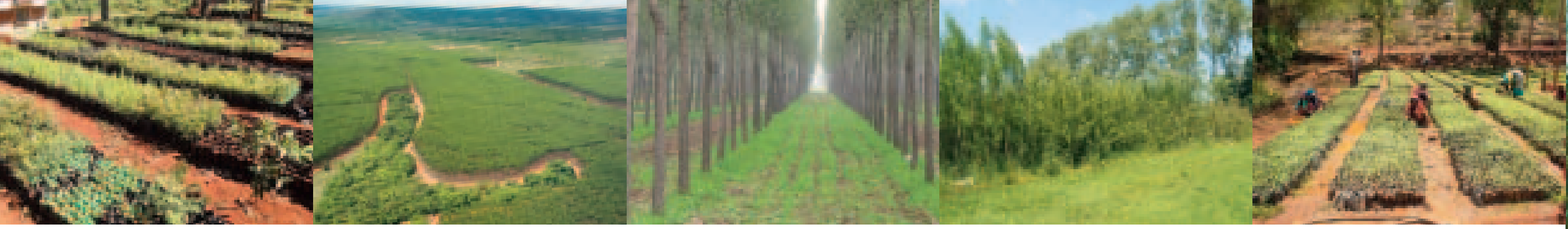
In Brazil, the PLANTAR Company introduced a complete mechanized harvesting method involving three main operation activities (felling, skidding and slashing): the felling process is performed with a tractor called a 'feller'; the cuttings are then dragged out of the stand using a 'skidder'; after this, the trees are slashed to their merchantable volume. The slashing is done with a machine called 'Garra Traçadora' (Slasher Claw).

During the whole production process, major attention is paid to applying sustainable principles to operations on-site with respect to the soil and the surrounding environment. Minimum cultivation techniques are applied to minimize negative effects on soil and other plants. Most of the forestry companies in Brazil adopt the minimum cultivation planting technique which seeks to preserve the environmental integrity of the area where the project activity is implemented. To protect and preserve the soil after harvesting, it is common to leave any harvest residues on the ground as a protective cover. Burning practices are banned to avoid soil erosion incidences.

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Impact of harvesting on understorey vegetation and soil.
2. Further research is required into the factors limiting forest productivity over a range of sites and conditions to determine the maximum rate of harvested biomass and nutrient removal that each can sustain (Walmsley, 2008).
3. SRF harvesting best practices. Harvesting technology for small or irregular stands.
4. Optimizing potentials for biomass transportation.



3.12 Transport and Storage

EUROPE

This chapter gives details of the logistics of transporting from field to end-user and typical storage and drying-processes carried out in different countries.

TRANSPORT AND INTERIM STORAGE AT THE FIELD

In Sweden, the trees tend to be chipped and then directly transported to the field´s edge, where they are left for some days (incl. drying) before being transported directly to the end-user. In Germany, for large heating and CHP plants end-users, the chipped wood dries on the field for about one week. In larger and more modern plants (i.e. special designed firebox with internal drying zone), humid material is mixed with dryer material; sometimes a flue gas condenser is additionally installed. In private or farmers' houses, the drying process will usually occur at a storage place near the boiler used for heating.

In Italy, harvested logs of five year rotations are stored at the edge of the field where they are then picked up by trucks. Harvested wood of two year plantations is chipped and blown onto a trailer which is positioned at the edge of the field; chips are then loaded onto trucks for transportation.

Deciding field logistics and transport to the client will determine costs of the operation. Some strategies for transport are given below.

:: TRANSPORT WITH TRACTOR DIRECTLY TO THE CLIENT

A tractor runs on the side of the chipping machine and loads the material. When the trailer is full the tractor drives directly to the end user. This is only recommended if the field is near the power plant, otherwise the labour costs for the driver will be too high due to the limited speed of the tractor.

:: TRANSPORT WITH EXCHANGEABLE CONTAINERS

The final transport in this case is done with trucks rather than tractors. Trucks can travel faster which generates the possibility to travel long distances without too high a cost. The chipping is done directly on the fields. The chips are directly blown into a container which is on a driving rack pulled by a tractor. This container is placed on the soil at the edge of the field from where it can be picked up by a truck and taken directly to its destination. With this technique it is possible to harvest 120 m^3 per hour under optimal conditions as the loading of 40 m^3 containers take around 20 minutes.

:: UNLOAD AND TRANSFER THE LOAD AT THE EDGE OF THE FIELD

It has been a trend to leave harvested material for some time at the edge of the field (after chipping) for drying purposes. For this, a tractor-pulled trailer unloads its cargo at an easily accessible place for interim storage.

This option gives the opportunity to decouple planning of harvesting logistics and planning transport logistics which can be done some after weeks after harvest. However, longer periods should be avoided in order to minimize loss of quality (cracks, pest attacks etc.). When wood is used for energetic purposes, drying at the side is an economical option (Guidelines, 2011).

Figure 28: Storage of splitted logs. Source: Christian Siebert, 2009.

STORAGE AND DRYING

Storage is defined as the time between harvest and consumption of a product (Figure 28). When storing wood there are different risks of storage, different storing techniques for different wood products, and different drying techniques for conserving purposes and increasing the calorific value, which need to be taken into account. The aim of energetic usage of renewable biomass is to maximize the energetic efficiency (Brummack, 2009). The following descriptions are based on Hartmann *et al.* (2003):

:: RISKS OF STORAGE

The storage of bulk material fuel has got some risks. There is the risk of loss of substance through biological processes, risk of self-ignition, and risk of development of fungi. Furthermore, unpleasant odour, rehumidification and reallocation of moisture content may occur which lead to a loss of quality. For chips it is important to mention that with temperatures around 5 °C the possibility of biological activity increases after a short time.

:: SELF-IGNITION

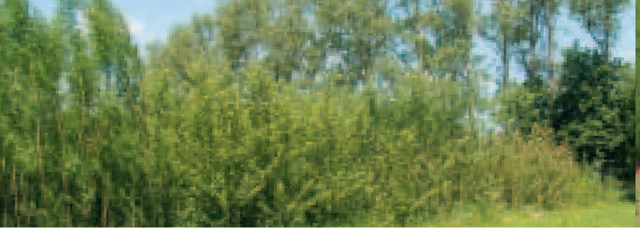
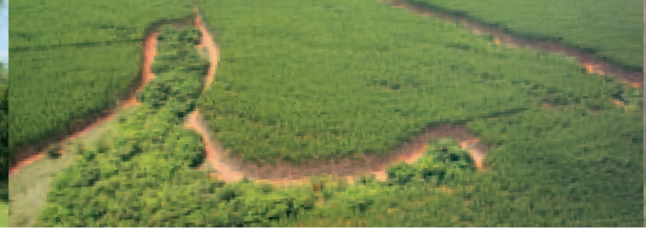
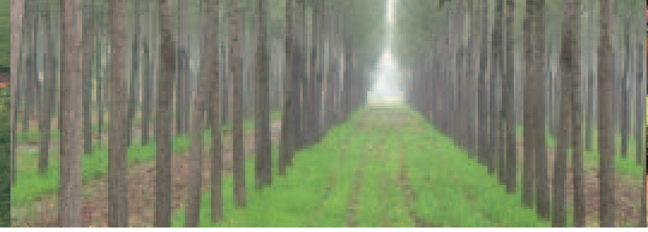
The risk of self-ignition is based on biological interactions between wood and bacteria or fungi. Due to such interactions, the temperature increases which can lead to self-ignition. Temperature rise depends largely on the moisture content of the material, the structure and density of the material, type of storage, surrounding area temperature and the level of contamination with bacteria and/or fungi.

:: LOSS OF SUBSTANCE

The growth of fungi and increased bacterial activity leads to a reduction of the organic substance. To reduce the risk of these activities, the following countermeasures should be implemented:

+ Achieve lowest moisture content as possible
+ Ensure there are no needles and leaves left (to avoid microbiological attack)
+ Minimize storage time
+ Shelter from deposition
+ Optimal dumping height
+ Raw material structure for long-time storage
+ Active aeration or sufficient passive aeration

Even if active aeration is started from the beginning of storage the loss of substance caused by biological activity is still about 4 %.

:: GROWTH OF FUNGI AND HEALTH HAZARD

There are different types of fungi that disintegrate wood. Ascomycetes, Deuteromycetes (mildew pudrity) and Basidiomycetes (white pudrity and brown pudrity) are mainly responsible for microbiological wood decomposition when wood is stored for a long time.

Cellulose and hemicellulose are decomposed by mildew pudrity and brown pudrity. Only white pudrity can decompose lignin, which is harder to decompose. For long-time storage, the relation can change in favour for lignin; there can also be selective decomposition of lignin which leads to a relation in favour of hemicellulose and cellulose, although this is rare. Lignin has a higher fuel value so any alteration of this part has strong impacts on the fuel value. The main determining factors for the growth of fungi are temperature and moisture content. The optimal moisture content is from 30–50% and the optimal temperature is 20 to 35 °C.

There is a danger of infection when people are relocating or shifting the material. The spores of fungi, which are developed during storage, get into the air where they can be inhaled. Different health hazards are possible, for example, Mycoallergosen ('Wood Chip Alveolitis' or 'Exogenous Allergic Alveolitis') which is caused by delayed reactions to repeatedly inhaling organic dust and, in former times, was called 'Farmer Lung', and Mycotoxications which are intoxications triggered by metabolic- and cell components of fungi.

In order to avoid the risk of infection, the following measures should be considered:

+ Storing unchipped or minimum pre-dried before storage
+ Shortening storage times
+ Reducing green parts
+ Raw chips (>50 mm) better drying => slower growing of fungi
+ Storing away from daily living and working places
+ Keeping storage areas clean
+ Optimizing aeration
+ Avoiding storage of clothes and food where wood chips are stored

:: STORAGE OF SPLIT LOGS

Split logs can be stored under-roof or in open-air. However, it has to be ensured that there is no secondary pollution and no soil humidity; this can be avoided by storing the split logs on wooden pallets or grit. Furnace-ready wood should never be stored without protection from rain. After two years of storing, split logs should have the optimal moisture content for energetic use. Rehumidification needs to be avoided so when storing split logs a natural entry of air to the stored wood from every side to remove humid air is beneficial. Furthermore, the distance to the wall should be minimum 10 cm and the storage place should be on the sun facing side.

Lastly, it is good if the daily fuel demand is stored for pre-drying in a heated room. In Germany, there are restrictions for the maximum storage weight for rooms without any fire protection systems. The maximum weight is 15 t which is equivalent to 31 stere split logs of beech or rather 43 stere split logs of fir.

:: STORAGE OF CHIPPED WOOD

Similar to split logs, chips have to be covered from rainfall and should be stored in dry places. They are usually stored in buildings or in silos (Figure 29). One possibility is the construction of 'Roundwood-Halls' which need no special permission if they not exceed a specific dimension that differs across States in Germany. If wood chips are stored in silos (round or square), it is easy to build an air vent for cooling and drying.

Another possibility for dry chipped wood is the 'Dom-ventilation-procedure'. This procedure uses tubes running along the bottom to get fresh air into the chipped wood and the chips are covered by a canvas cover. A stove make extracts the moisture out of the chipped wood.

Figure 29: Building for wood chip storing. Source: BE 2020+, 2010.

:: DRYING

Drying is not only for wood preservation purposes but also to increase the fuel value, reduce the weight and improve the quality. For many firing-systems, drying is essential. At the beginning there are some basics which have to be mentioned. The background for planning dimensions of drying facilities is the h,x-diagram depicted by Mollier (Hartmann *et al.*, 2003) which describes the relations between temperature, moisture content, relative air humidity and energy content of the air. If these aspects are known, the maximal absorption of water through air can be estimated. For example: with a temperature of 18 °C, moisture content of 6.3 g/kg, and 50% rel. air humidity and drying through air ventilation which saturates the air with water to the maximum (8.8 g/kg), there will be a maximum drying capacity of 2.5 g/kg air.

There are two kinds of methodologies for wood drying which have to be differentiated, namely natural drying and ventilated air drying.

:: NATURAL DRYING

Natural drying is done without any kind of climate-technical installation. Possibilities of natural drying are drying on the ground, natural convection drying and self-warming.

When the drying occurs on the **ground**, the material should be spread on an area as wide as possible. This method is used in agriculture for drying green material and it can also be used for drying wood. Drying on the ground can be done directly after felling. Hardwood dries faster if it is felled with leaves as H_2O dispensing to the air is higher than without leaves. Logs which are stored under open air can reach moisture contents of up to 30%, but for this to happen it is necessary that the logs are not stored in forests.

Drying on the soil is also possible for wood chips. If the chips are exposed to good solar radiation and the dumping height is low, the dehydration rate can reach nearly 20% per day.

Another method is drying through **natural convection**. Fresh material dries though this method over a period of one or two years. Rough chips can also be dried through natural convection. Special reservoirs or buildings are used for this kind of drying. The buil-dings have to be designed with a roof and with a wall of slatted frame or fence. This method of drying is preferred for small customers.

The drying of bulk cargo through natural convection is often supported by **self-warming**. The warmth is generated by the decomposition of organic substances. A further advantage is, if the bottom of the stored wood is permeable to air, the ascension of the warm air leads to streaming in of fresh and drier air.

:: DRYING THROUGH VENTILATION

The method of drying through ventilation uses cold air from outside to dry the wood. Self-warming heightens the saturation deficit of the air and through this kind of ventilation the moist air is replaced by new air. The ventilation cycles are mostly steered by temperature. The advantage of this is that the demand of external energy is lower than using a permanent aeration method. A disadvantage is that during wintertime the reduction of moisture content is lower.

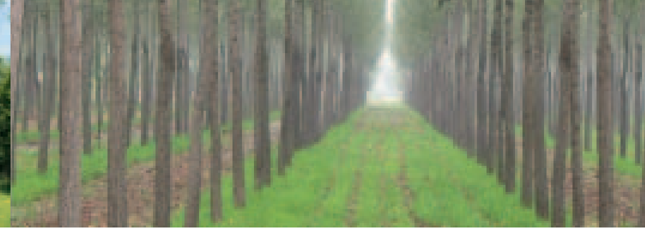
At the beginning of the warm season, the saturation deficit of the air outside rises and permanent ventilation leads to an acceleration of the drying process. Technical measures can also be undertaken to accelerate the drying process. One possibility is solar heated air, whereby, air is heated in the roof of the storage building and after heating is pumped to the bottom of the building from where it ascends through the wood material and dries it.

The pre-warming of air increases the drying effect. Pre-warming from 20° C up to 100° C is possible. The decision of ventilating using air from the outside or with warm air depends on the maximum available drying time.

:: DRYING FACILITIES

The drying of wood chips happens in combination with storage. One option for drying and storing is the batch drier. The basic construction is a ventilation bottom (best with small holes) or ventilation channels through which a generator blows air into the bulk cargo. There are different forms of batch drier and they can be built in houses as well as on trailers to reduce movement costs.




KENYA INDIA CHINA BRAZIL

KENYA

From the field to the vehicle, transport is mostly done by people carrying the cut logs on their backs. If there is a longer distance to the nearest road accessible by truck, logs will be carried by a smaller vehicle or bicycle to the truck. Timber or logs are transported by road using open trucks that allow loading from either side or from the back. The logs are cut to the size of the truck and secured on either side after loading. Except for a few big timber companies, all timber is loaded manually in Kenya and load weight is controlled by the Traffic Act of Kenya.

Logs meant for sawn timber are usually harvested and transported immediately to the processing mill without keeping them in the field. They are arranged purposely to ease the work during processing but not for any other purpose. Wood meant for transmission poles is left lying on flat ground where it is cut to avoid bending and to give it time to lose moisture in order to reduce load weight.

Wood is air dried after the processing. For most processing sawmills, they stack the processed timber by size without too much consideration about the drying aspect. This is because the demand of timber does not allow any appreciable time to elapse before sale. However, at timber yards, beside timber being stacked by size to allow easy selection during sale, gaps are left to allow for drying but no sticks are placed between individual planks of timber as would be expected in a long-term drying process.

Some few companies have kilns that they use to dry timber for specific end products but as this process uses electricity and is expensive, it is limited in use.

In general, the time it takes for wood to dry is dependent on two parameters which are: the initial moisture content of the logs and the size of the processed timber. A 15cm wide by 2.5cm thick plank of timber normally takes three months to air dry while a 10cm wide by 5cm thick plank takes up to six months. This however may vary with tree species and the time of year the tree was cut.

INDIA

In India, the market and depots receive a large percentage of their timber supplies by surface transport (truck/tractor-trailer). The rates are mostly competitive but accurately determined by taking the cost into account (distance, weight, depreciation, taxes, road conditions, interest, fuel cost, etc.). The average loading capacity of the trucks is around 10 tons.

Logs, sleepers, poles, fuel wood, etc. are stored in stack form and all these stacks are classified and usually numbered and labelled to enable easy inspection by buyers. During storage, the wood is dried simultaneously and, depending on the storage method, different results of drying will be achieved. The air drying method is commonly used because it does not require a large initial investment for buildings and equipments, but it does require timber to be held in yard storage for a considerable time before it is ready for market. In contrast, kiln drying requires a comparatively large capital investment, but dries the wood in a short time and can provide dry timber for all seasons of the year unlike air drying.

Generally, the time required for air drying depends on the species, the prevailing climatic conditions of the locality, the type of material (log/chips) and the method of storage.

Figure 30: Manual transport out of the field. Source: PAU, 2010.

CHINA

In China, moving timber from forest to the forest edge is mainly carried out using animal-drawn vehicles, tractors, slide, aerial cable ways and winch machine tools.

The next step is transport from the plantation/forest edge to storage facilities or other destinations. If the transport occurs over land, trucks and railways are usually used. If the transport is by water, river drift delivery and shipping is applied.

Storage methods can be divided into storage before drying and storage after drying. For storage before drying, timber should be configured according to the main wind direction. Timber which is easy to dry should be placed windward, whilst timber which is harder to dry should be placed leeward and any other timber should be placed inbetween. Timber stacking is boosted to ensure that the bottom of the timber has good ventilation so that air can move freely. When stacking wood, skids are used to separate layers to keep wood straight and to improve air circulation. The size of the crib is related to wood species, size, specifications and equipment used for accumulation. Additionally, when stacking the wood a gap should be left between the wood to form a vertical air channel.

Wood drying can be divided into natural drying and artificial drying and each comes with advantages and disadvantages. For natural drying, although it is difficult to control the conditions of drying, the time of drying is long, a large space is needed and wood can be easily damaged by insects, on the other side, the method is simple, easy to implement, energy efficient and more economical. Because of these advantages, the natural drying method is currently widely used in China. There are many types of artificial drying methods using various equipments and the advantages are that the process can be controlled to a high degree (including final moisture content), the drying cycle is shorter than the natural drying, the drying process is not affected by region, season and climate. The main disadvantage of artificial drying is the cost involved and technical expertise required.

BRAZIL

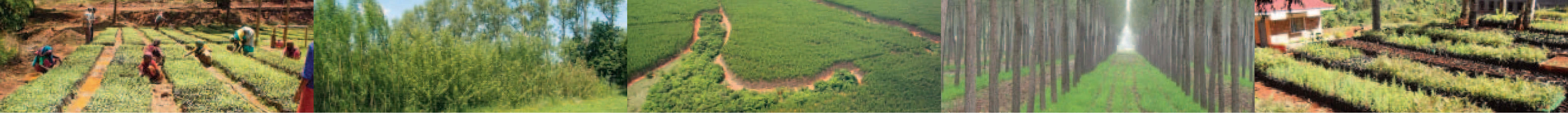
In Brazil, the wood that has been felled is left on the planting site for at least 90 days in order to get the desired humidity for the carbonization process and is then usually transported with trucks to the final destination.

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Energy efficient drying techniques for wood chip require more research and development.
2. Optimization of supply chain from forests / agroforest sites to end-user. Product optimization of SRC/SRF plantations on-site to increase product value and allow transport to higher distances.
3. Improve compaction techniques for wood chips to reduce the volume or moisture content for easier transportation.

Figure 31: Long distance transport with trucks. Source: Plantar, 2008.



3.13 Utilization of Wood

EUROPE

In Europe nearly all of the harvested goods from SRF plantations are used for energy purposes (Liebhard, 2007; Schmidt *et al.*, 2010; Sims *et al.*, 2006) and its importance will grow. Utilization options are:

+ Wood chips for production of heat
+ Raw material for wood pellets/ briquettes
+ Raw material for production of synthetic fuels (biomass to liquid)
+ Production of charcoal, used mainly as a reducing agent in the iron and steel industry

As poplar is one of the most dominating SRF species in European countries, the different possibilities for wood utilization are demonstrated using the example of poplar. However, the utilization of other wood species can be adapted, accordingly.

Figure 32: Biomass boiler with 200 kW. Source: BE 2020+, 2010.

MATERIAL UTILIZATION OF WOOD

:: UTILIZATION OF POPLAR WOOD

Poplar wood is characterized by a relatively high cellulose content which can fluctuate within a big range. The high occurrence of tension wood cellulose is found in all poplar species, with roughly 60 % of the wood composition belonging to fibres.

Poplar stems contain a lot of moisture, with the heartwood being about 60 % more moist than sapwood and needing more time for drying as a result. Poplar wood shrinks moderately; however, tangential shrinking is much higher than radial shrinking which can lead to cell collapse during drying.

The relatively high resistance to cleavage and, therefore, the bending strength is remarkable. The lateral hardness determined by the 'Brinell' test proved to be low. With well dimensioned branchless and defect-free poplars, it is possible to produce sawn timber or wood veneer without any problems, using accurately adjusted cutting tools.

:: POPLAR SAWN TIMBER

According to the physical characteristics, one may think that poplar wood is easy to process but this is a mistaken belief. Fibre bundles get easily ripped out and complicate precise cutting, and tensioned wood fibres within the stem can warm up or clamp the chainsaw. Zones with compact tension wood may occur rough and woolly after cutting which complicates further processing.

Drying of tension-free sapwood is possible within six months depending on season and quality. Error free drying becomes more complicated with tension wood as its moisture has to be lowered slowly which implicates higher costs.

Poplar timber is used because of its favourable stability/weight ratio. It is light weight, abrasion resistant, nail-holding ability and resistance to cleavage. The surprising resistance to abrasion and wear is due to its fast felting and compression of the stressed surface. In this case, tension wood and woolliness may have positive effects.

:: POPLAR WOOD VENEER

Poplar wood has been used over a long time for chipless production of veneer using wood peeling machines. Fresh poplar wood can easily be stripped without prior water storage due to its high moisture content and relatively soft structure.

Veneer from poplar wood is often light coloured without striking early- and late wood contrast, the surface is smooth and it has a high endurance. Furthermore, it is also usable for face veneer and light veneer panels. Darker heartwood becomes lighter after drying and little difference can be noticed.

However, branchiness and tension wood, mostly in combination, harbour the potential to interfere with peeling operations. High differences between the humidity of sap- and heartwood also make drying difficult. In tension wood areas the surface may become waved and, due to unequal shrinking, the veneer thickness may vary resulting in higher glue consumption.

:: POPLAR WOOD CHIPBOARD AND CHIPBOARD MOULDING

According to Klauditz and Stegmann (1958) the gross/oven-dry density of poplar is favourable. Therefore, lower energy input during chipping is needed where there is a larger surface per weight ratio of wood chips and a positive utilization ratio of binder per weight unit. Additionally, a relative early stabilization of glued compounds can be achieved, keeping plasticity (minor transverse pressure stability) of the product and allowing the fabrication of closed edges and surfaces.

Additional advantages of the wood product are:

+ Bright colour
+ Broadly odourless
+ Resin-free raw material
+ Good wood chip wettability within the mixer

However, there are also several disadvantages: if the cutting machinery loses its sharpness, knives may be blocked as fibres lay over the edge (felting) and the continuous feeding of the chipping machine will be disturbed resulting in increased energy consumption. This problem is mainly observed for timber with many branches and tension wood areas. However, if this material is mixed with 'normal' wood, felting can be prevented.

:: FIBREBOARDS FROM POPLAR WOOD

Baldwind and Yan (1968) describe the wood characteristics during the processing of hard fibre boards. Poplar wood is easier to fray out when compared with denser deciduous tree wood and some coniferous wood. Thus, homogeneous fibres may be produced which is an important requirement for the production of homogeneous boards.

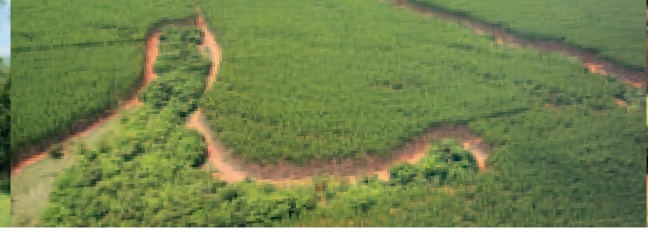
Poplar fibres are highly competitive against other wood types within the fibreboard production process as well as for fibreboard characteristics. Optional bark residues do not decrease the panel quality and disturbing sclereid can be removed via 'centric leaner'. Poplar fibres are shorter than coniferous fibres, and the low lignin content and light colours are important basic qualities for successful usage.

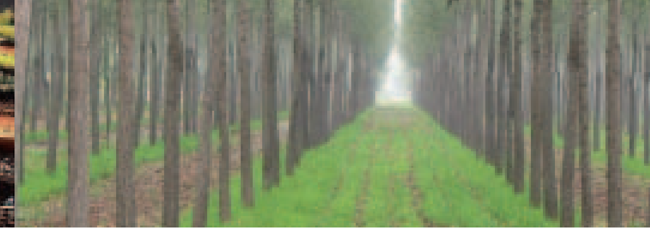
CHEMICAL UTILIZATION OF POPLAR

:: MECHANICAL PULP FROM POPLAR

For poplar, the technique for mechanical pulping has to be optimal and adapted to its structures. Brightness is particularly favourable from grinded green poplar wood. Brightness is about 67 up to 70 % within poplar (compared with only 64 % within spruce) and the brightness level can be increased to approx. 82 to 88 % via bleaching. Poplar mechanical pulp with and without heartwood has a higher light stability than spruce, therefore, when using poplar wood the proportion of grind can be increased without lowering light stability (Feldmühle, 1974).
The admixture of poplar grind with spruce grind for producing newsprint paper lowers burst pressure significantly and, within the printing paper production, poplar is often regarded as filler material. The insertion of poplar grind shows technical advances for producing carton, but the field of application is limited by the speed of the machinery which normally operates with 600 m/min (Augustin, 1973).







EUROPE

KENYA

:: POPLAR FIBROUS MATERIAL FROM SEMI-CHEMICAL PROCESS

Poplar wood has great characteristics for semi-chemical digestion due to its homogenous fine construction and low lignin contents. The stability of the resulting fibrous materials is higher than material exclusively produced with mechanical digestion. Especially the brightness and light stability of the mechanical pulp production can be emphasized. However, aggregation characteristics, opacity, whiteness and bleach ability may be lower. Poplar is particularly successful when used within the NSSC-process (NSSC= neutral sulfite semi-chemical).

The poplar-NSSC fibrous material is mainly used combined with mixtures of other hardwood fibrous materials for producing corrugated boards. In combination with coniferous fibrous materials, it is additionally used as filler materials for newsprint papers (Clayton, 1968).

:: SULPHITE FIBROUS MATERIAL FROM POPLAR WOOD

Poplar-sulphite-pulp is characterized by its whiteness, bleaching capacity, opacity and absorbency. The digestion methods of magnesium- and sodium bisulphite are superior to the usual calcium bisulphite process.

Fischer-Zach (1965) compares the characteristics of spruce-sulphite-pulp and various hardwood pulps. In relation to this, beech and poplar pulp are shown to have the lowest breaking length. Moreover, the exceptional high opacity of poplar compared to translucent spruce has to be highlighted. Standard sheets of poplar material are lightly structured (low density) and have a high absorbency which is two to three times higher than that of spruce material.

:: SULPHATE FIBROUS MATERIAL FROM POPLAR WOOD

The sulphate process results in a high yield and carries out a careful fibre separation. Poplar-sulphate-pulp reaches a high sheet volume with good opacity and printability, but has a low strength.

It is recommended to digest poplar wood on its own and to mix it directly with fibrous material which increases its stability. Hardwood kraft-pulpwood which contains 10 to 15 % poplar is used for book printing.

:: CHEMICAL PULP FROM POPLAR WOOD

There have been reports stating that poplar wood does not seem to be suitable for producing pulp as basic material for rayon, chemical fibres or 'cellophan' (Stegman, 1956) and problems occur in sulphite digested pulp within accessory wood components (Augustin, 1973). Another study suggests that dehydration of the short-fibred material may delay the allocation of alkaline cellulose for the viscose process (Clayton, 1968).

OTHER USAGES OF POPLAR WOOD

Dry heartwood as well as sapwood is largely odourless and its easy processing ability makes poplar wood a suitable raw material for wood wool production, e.g. as packing material or wood wool boards. Many uses of poplar wood, especially for handicrafts, have been described by Knigge (1959) and Kesemeyer (1969):

+ Kneading or butcher troughs
+ Accumulator lamella (low acidity)
+ Matchstick production
+ Prostheses
+ Sauna seat benches
+ Snow shovels
+ Stir sticks
+ Cheese packaging
+ Chip baskets
+ Polishing wheels for glass
+ Jewels or mirror industry
+ Horse-boxes
+ Stables or silos

Charcoal made from poplar contains a high proportion of carbon and its porosity is approximately two – two and a half times higher as that made from beech; therefore, it is used as special charcoal for drawing within the chemical industry and for jewel polishing (Koltzenburg, 1971).

ENERGETIC UTILIZATION OF WOOD

Nowadays, the energetic utilization of biomass for renewable energy production is getting more public attention, and producing biomass on SRF plantations on a larger scale is a possible scenario for the future. EU countries have set targets that they are hoping to meet with regards to renewable energy production. In Germany, for example, the percentage of renewable energies has been increasing since 1998 and 8.8 % of the heat-production is now delivered through renewable energies. The emphasis on renewables is due in part to national strategies on energy source and production in the light of there being finite amounts of fossil fuels, and also because of the damaging effects of fossil fuel based energy production in terms of CO_2 emissions.

KENYA

In Kenya, SRF trees are utilized as follows: the bottom part of the main stem is used for timber, the top for poles or posts, the branches and tops as fuel wood while the foliage remains as mulch or if the trees species is palatable the foliage is used as fodder for the animals. Remaining stumps and roots are used for charcoal. It is not common to find wastage from trees as there is a high demand for all the products gained from a tree.

Paper is produced from logs of mainly *Pinus patula* grown in short rotations for 15 years that are not subjected to pruning and thinning operations. Furthermore, different parts of a tree are used for medicinal purposes mainly depending on specific tree species. These parts include the roots which are dug out, the stem bark which is normally peeled from living trees, the twigs and leaves, flowers, seeds and fruits. Among some trees, sap collected after inflicting some injury to the stem is utilized for medicinal purposes. Below is an example of some of the short rotation forest species and their medicinal uses:

+ *Acacia mearnsii* – leaf and bark (Kamatenesi-Mugisha, *et al.* 2008)
+ *Cupressus lusitanica* – powdered dry gum resin applied as a drying agent for wounds (Gachathi, 2007)
+ *Calliandra calothyrus* – honey produced by bees that forage on the species has a bittersweet flavour
+ *Eucalyptus camaldulensis* – honey produced from its nectar is clear pale in colour with a mild pleasant flavour
+ *Grevillea robusta* – flowers are attractive to bees thus an important honey plant
+ *Prosopis juliflora* – flowers are a valuable source of nectar for high quality honey
+ *Gmelina arborea* – flowers product abundant nectar which gives high quality honey (NAS 1980)
+ *Melia volkensii* – bark is used for cure of pains and aches in the body (Kokwaro, 1993)

Despite the abovementioned fodder, mulch and medicinal utilities, the main purpose of SRF wood is fuel wood and timber.

UTILIZATION OF WOOD IN AN AGROFORESTRY CASE STUDY

Illegal deforestation for valuable timber and charcoal making can lead to governmental restrictions on access to forested areas and reduces the availability of land, trees and their products to local farmers and their livestock[2]. A project was developed together with experts from the FAO, in the vicinity of the Mau Complex in Kenya, to address the problems a community neighbouring the forest is facing. Within three kilometers of the forest borders, communities were motivated to establish agroforestry sites for subsistence and income generating purposes. Products from the agroforestry project are timber and fuelwood, leaves for fertilization, newly cultivatable land for growing maize and pyrethrum and several other side uses. Furthermore, the pressure towards the natural forest resources has declined in the locality. This example shows that the practice of agroforestry and utilization of agroforestry products can have far-reaching effects on surrounding areas.

[2] http://www.trust.org/alertnet/news/mau-farmers-defy-political-intrigue-to-protect-endangered-forest/

Figure 33: Veneer production. Source: PAU, 2011.

INDIA

In India, the different parts of the trees are mainly used for the following:

+ Wood from the main stem is used for fuel, pulp, timber, plywood, packing cases for fruit and foodstuffs, furniture (Figure 33), doors, window frames, crates, pencils, toys, walking sticks, wood carvings
+ Branches are used as sources of fodder and fuel, and they yield fibre which can be used for roap making
+ Bark is used for fuel and constitutes one of the most important tanning materials
+ Roots are used in native medicines or fuel
+ Tree tops are used as fodder and fuel
+ Leaves can be utilized for production of biogas, fodder, medicinal purposes, mulching, needles of conifers are used for packaging purpose
+ Saw dust is used for fuel or packaging purposes

Paper is mainly produced from soft woods like eucalyptus, leucaena, casuarina, poplar, wattle, bamboo and pines. The main purposes of SRF are:

+ Fuel: direct use of wood is as fuel for thermal/electricity purpose
+ Construction and furniture: door and window frames, crates, pencils, toys, walking sticks, wood carvings
+ Decorations: decorative features in wood like grain, colour and composition of the cells or tissues which ultimately impart decorative properties to wood
+ Paper making: SRF timber is an important raw material for the production of paper and pulp
+ Artificial board: SRF wood is a source of plywood for domestic and industrial use

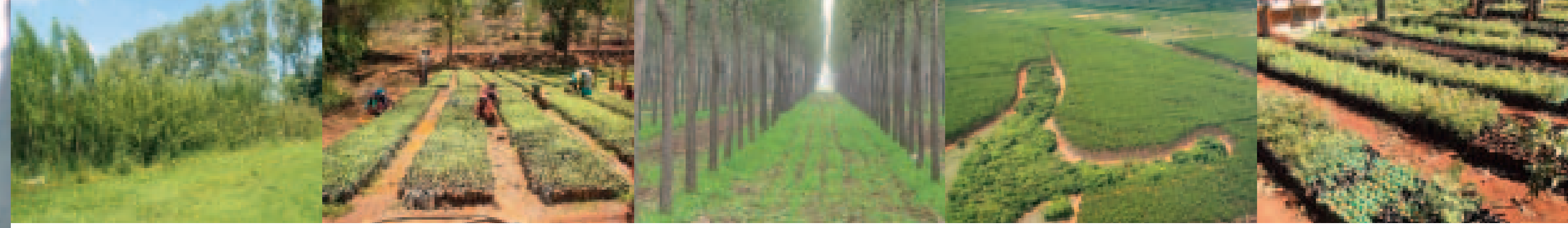
CHINA

In China, the current utilization ratio of residues after logging in forest areas is above 90%. the main stems of the harvested tree are used in the wood-based panel industry and the pulp and paper industry. The branches are used as fuel wood for local residents, wood chips, block boards, carbon for industry and sanitary chopsticks (edible fungi is also harvested from branches). Tree tops, bark and roots are used as fuel wood. Leaves are sometimes used to produce beverages and roots are sometimes used to make root-carving artworks. In recent years, there have been some new ways of using harvested trees. For instance, residues after logging have recently been used to manufacture pellet fuel and harvested trees have been used to manufacture bio-oil through the method of thermo-chemical conversion.

The paper industry in China makes use of recycled pulp, wood pulp and non-wood pulp. The 2008 national statistical results showed that recycled pulp makes up 60% of total pulp, wood pulp 22% and non-wood pulp 18%. The materials used for wood pulp and papermaking come from coniferous trees (such as spruce, fir, red pine, larch and masson pine) and broad-leaved trees (such as poplar, birch, maple, eucalyptus and zelkova). The main materials used for non-wood pulp and papermaking include bamboo, straw, wheat straw, reed, cornstalk, cotton stalk and hemp.

Various parts (bark, leaves, roots and fruits) of many trees can be used for medicinal purposes: the leaves, roots, fruits of acacia; the bark and roots of *Phellodendron amurense Rupr.*; the bark of *Eucommia ulmoides*; the bark of ground hemlock, and the bark or twigs of *Ailanthus*.

The main purposes of SRF in China are panels, pulp, wood chips, block board, industrial charcoal and fuel wood. There have been newly developed uses of SRF such as making pellets, producing chemicals or transport oil using thermo chemical transformation, but these are not widespread yet.



INDIA CHINA BRAZIL

BRAZIL

According to ABRAF, industrial wood processing in Brazil is divided into primary, secondary and tertiary processing and usage, each with their own production flow in the respective forestry sector segment.

Primary processing refers to log transformation into a number of products: wood chips, sawn wood, veneer, chemically treated logs, and charcoal, besides energy. These subsequently will give rise to other differentiated products, according to the specific industry segment. The subsequent phase is the secondary processing which is the processing of primary products into final or intermediate products for other processing.

Wood chips form the raw material base for the manufacture of reconstituted wood-based panels such as Medium Density Fibreboard (MDF), Medium Density Particleboard (MDP) and Oriented Strand Board (OSB). Wood chips are also the main raw material for pulp mills. Additionally, wood chips and tree bark are widely used in direct combustion to meet the demand of different energy-generation processes. From solid wood, resulting from second processing, the high value-added wood products (VAWP) are manufactured. This includes clears, blocks and blanks (solid wood planed on all four sides, free of defect) which themselves are a raw material for finger-joint frames, doors, staircases, flooring and EGP (Edge Glued Panel) production. The VAWPs, which differentiate into more value-added level, are related to the furniture sector.

The first products from sawn wood, which can be passed directly to final consumers, are beams, rafters, battens, treated wood and wooden boxes.

Another product base for secondary processing is the primary product veneer, either veneer peeling or slicing, for manufacturing decorative or structural plywood. Veneers can also be used for laminate flooring.

Fuel wood is used to produce charcoal, widely utilized for production of pig iron and steel. Moreover, firewood can be directly used for power and steam generation for the benefit of grain dryers and ceramic industries.

Tertiary processing adds the highest economic value to solid wood products. Products made from wood pulp also have a high added value, e.g. printing paper, cardboard and corrugated packaging. Currently, it is possible to find fabrics made from pulp as a result of high technologies and applied research in the forest products sector. Wood residues accrue at all stages of the production chain and are considered by-products; as a common practice, they are not discarded in the manufacturing process. The industrial sector integrates these by-products into the production process which increases industrial productivity and reduces wastage or potential environmental liabilities.

In the timber industry, wood residues from mechanical processing, including bark, slabs and sawdust, are destined for burning in boilers to produce steam used for wood kiln drying, or in furnaces for generating hot gas or heating fluids. There is also the recovery of wood residues from wood chip production for further commercialization and is currently a booming market. Another industrial use of wood residues is the manufacturing of wood pellets and briquettes and in semi-industrial processes the production of wooden utensils, interior design wooden objects; this adds value and creates an alternative market for material that otherwise would be discarded.

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Carbon sequestration potential of different SRF systems and resulting wood uses, modelling compartments and sequestration.
2. Optimal side uses and impacts of SRF, e.g. phytoremediation (Jones, 2005), watershed management (Nair, 2011), research on the quality parameters for SRC wood, problems of high content of sulfur and chlorine in the wood.
3. Drying options for harvested wood from SRF/SRC systems: efficiency in terms of time and financial/energy cost.

EUROPE KENYA

3.14 Recirculation to Cropland

Figure 35: Rotary hoe. Source: Thomas Lewis, 2007.

EUROPE

The following information is mainly based on Becker *et al.* (2009).

After 20 years of use, there are certain procedures that need to be followed for converting a SRF-plantation area back into cropland and reclamation of the land. This has to be carried out in order to shred the residual dendromass like rootstocks and roots. Residuals have to be removed and the soil structure has to be prepared for agricultural use. The area will also need to be enriched with sufficient nutrients.

Regarding recirculation to cropland, different rotation lengths of the former SRF plantation will pose various problems. While 10 year old poplar rootstocks can have a 30 cm fellcut diameter and big roots to contend with, shorter rotation periods lead to smaller rootstocks but with more shoots. The percentage of remaining dendromass after final harvest depends on the height of the rootstocks; for example, the remaining dendromass of a 10 year old poplar plantation (1600 trees/ha) can be up to 25 t DM/ha (Große *et al.*, 2009).

For recirculation of SRF, the shredding and mixing of the roots and rootstocks should be undertaken with minimal damage to the different soil layers. There are different options like selective shredding (diameters > 30 cm) or stripe- and area shredding of rootstocks. Shredding of the whole area is favoured if the land is going to be used primarily for agriculture.

The first step of shredding is using the rotary hoe. The rotary hoe has a working depth and width of about 40 cm and 200 cm, respectively (Landesamt für Umwelt, Landwirtschaft und Geologie, 2009). The high energy demand of the rotary hoe makes it necessary to use only for the rows of rootstocks; for the residual area, the use of a mulcher is recommended. The size of the shredded dendromass depends on the driving speed during the cultivation. Große *et al.* (2009) report a reduction of big parts of dendromass by up to 50% by reducing the speed from 0.8 km/h to 0.2 km/h. However, the working area also decreases with the reduction of the speed, from 0.2 ha/h to 0.05 ha/h. It is necessary to minimize big wood residuals (>200 mm) because they have a high resprout capacity and, depending on the plant numbers, resprouting may reach up to 35% (Scholz *et al.*, 2009).

After shredding the dendromass, the area should be treated with a field cultivator or a disc harrow which is also beneficial regarding the risk of resprouting. The choice of the following crop to be planted is also important to consider; in the first instance, it should be a relatively undemanding plant regarding the quality of the seedbed, e.g. spring grain (Scholz *et al.*, 2009), maize or clover grass Becker *et al.* (2009). To achieve a good seedbed, standard agricultural procedures should be applied.

The costs of implementing a recirculation procedure range from between 1000 €/ha (Hofmann and Siebert, 2010) and 1500 €/ha (Becker *et al.*, 2009). This would include costs for two times of milling and the use of a disc harrow. However, the costs for recirculation to cropland do also depend greatly on the type of soil and the size of the rootstocks.

Figure 34: Stump grinder. Source: Thomas Lewis, 2007.

KENYA

SRF should be practiced in specific areas where management systems can be put in place to ensure that during harvesting, biomass from the tree tops, twigs and foliage is left to decompose on site. The litter fall from such forests should not be collected during the rotation to leave the site clean as this amounts to removal of nutrients that are being recycled from deep soil horizons. Specific sections of the forests must be left to naturally regenerate where indigenous tree and shrub species grow. Such areas should be protected from both human and livestock activities for a specified period so that even palatable tree and shrub species regenerate and survive future biotic and abiotic interference.

Another way of addressing soil productivity is through growing trees and/or agricultural crops that improve the soil fertility. These would be mainly leguminous trees/crops that are nitrogen fixing in nature.

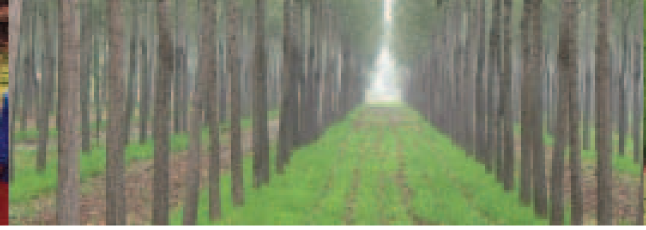
The recirculation of land from SRF to crops is not commonly practiced by individual farmers in Kenya. However, companies such as East African Tanning Extract Company (EATEC) used to grow *Acacia mearnsii* for four to five rotations before growing agricultural crops for two to three seasons. During the growing of crops, shrubs and bushes that could have established were cut to eliminate potential competition for nutrients and soil moisture. Among the pulp wood plantations crops were grown at the end of the rotation mainly to prepare the ground for new planting. In this case, the forest department benefitted in that the field was prepared at no cost while the farmers benefitted through harvest of crops without paying land rent.

For farmers growing *Casuarina* at the coast, crop harvests in fields that were previously plantations of *Casuarina* are better than from fields continuously planted with agricultural crops. The benefits accrue from the improved nutrients status of the soil due to the N-fixing characteristic of *Casuarina* and the extensive litterfall accumulated in such plantations during the rotation.

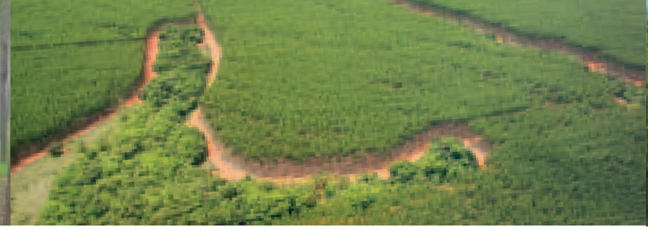
In contrast, where plantations are grown with *Eucalyptus saligna* or *Eucalyptus grandis*, the land needs time to recover before growing productive crops. In some cases, farmers will burn the land of the remaining debris and stumps to prepare the land for planting crops; otherwise it can take many years for the land to be productive again for anything other than trees.

It has to be taken into account that certain fast growing SRF species have adverse chemical/biological effects leading to acidification, allelopathy, accumulation of toxic exudates, etc. Therefore, the farmer should be cautious before planting crops on that land too soon after the SRF cultivation.

INDIA



CHINA



EUROPE

3.15 Economics and Financial Issues

INDIA

In India, the expensive recirculation process is avoided by careful species selection from the beginning. Excessively exploitive species are therefore avoided, e.g. farmers prefer to plant poplar over eucalyptus. Invasive species may be restricted or managed properly, for example leucaena is seen as invasive due to its excessive seed bearing (twice a year) and its profuse natural regeneration. However, proper site selection for leucaena and lopping the branches for fuel/fodder at the flower/pod formation stage helps in managing its wild growth.

Absent land owners tend to shift from annual crop cultivation to SRF because of their other commitments; this way they protect their land from illegal encroachment and avoid regular crop cultivation (which would be costly to maintain).

CHINA

In order to avoid declining soil productivity, the following strategies for poplar and eucalyptus plantations are followed in China:

Poplar:

+ Mixed plantations (poplar and black locust, poplar and *Amorpha fruticosa*, poplar and *Hippophae rhamnoids*)
+ Intercropping
+ Replacing the sand with soil

Eucalyptus:

+ Choosing species suitable for introduction
+ Reducing the intensity of site preparation
+ Changing the stand structure and tree structure (mixed and multi-species)
+ Increasing the fertilization amount

According to the Forest Law of the Peoples Republic of China and Regulations for the Implementation of Forestry Law of the Peoples Republic of China, forest lands should not be changed into non-forest land.

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Research of CO_2 emissions after recirculation.
2. Decomposition of organic bound carbon compounds in roots and the extent to which the carbon will stay in the soil.
3. Comparison of species suitable for SRF and their impact on future recultivation efforts.

EUROPE

Certainly a promising return of investment is an important factor for future success of SRF systems. Whilst costs get generated during plantation initialising, maintenance, harvest and recirculation (Stürmer, 2007; Defra, 2004), on the other hand the economic situation depends on planting method, plant density, rotation period, harvesting technology, logistic chain, harvested biomass per ha and revenue for the produced biomass. All these factors can influence each other and do not allow a general overview about the economic effectiveness. SRF systems in Europe also heavily rely on subsidies (e.g. Energy Crops Scheme (ECS)[1], SRC Scheme[2], Scotland Rural Development Plan[3]).

Monetary issues have a high impact on the decision-making process of whether or not to practice SRF/AF. The area for planting is assessed for the most viable and profit-making option, whereby SRF is compared with other alternatives. This chapter deals with methods of comparing SRF with the cultivation of annual crops.

:: METHODS OF PROFITABILITY COMPARISON

First there are ***static investment calculations*** which should only be used when short periods are envisaged and being assessed. Time effects, costs and proceeds occur at different times, however, these aspects are not adequately observed. This does not pose a problem for classic annual crop cultivation but if the observation period is longer the use of amount of coverage will usually over- or underestimate the profits or deficits.

Dynamic investment calculations work with cash flows and the time of each payment. For SRF, costs are incurred at different times for acitivities such as planting, cultivation, maintenance, harvesting and recirculation. Through closing of rediscount- or accumulate earning and payments at one point in time the capitalised value (CV) can be calculated as shown by the following equation:

$$CV = \sum_{t=0}^{n} \left(\frac{E(t)-A(t)}{(1+t)^{i}} \right)$$

Equation 1: Calculation of capitalised value (KW).

A positive CV shows that the investment is profitable. This investment calculation method is used when two investment options covering the same time period are compared.

If investment options with different time periods need to be compared, the annuity method is the best to use. Annuity is a periodic and constant payment through the investment period and all payments and earnings are accumulated into one annual amount. Annuity is calculated by multiplication of the CV (*Equation 1*) with the reclamation factor and the CV is transformed into an annuity (r; *Equation 2*):

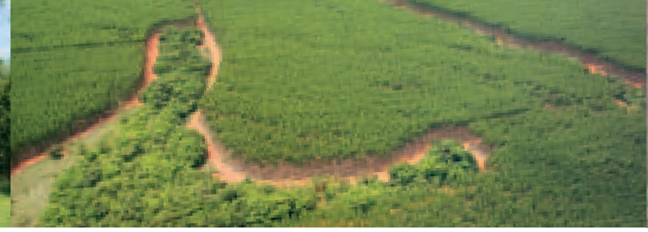
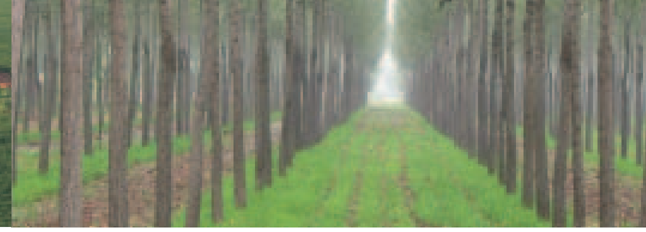
$$r = CV \bullet \frac{(1+i)^n \bullet i}{(1+i)^n - 1}$$

Equation 2: Calculation of the annuity.

Through mathematical transformation, annuity is equivalent to CV. Investments with a high annuity are to be preferred from an economical point of view. With the help of the annuity method SRF can be compared with annual crops; for further details refer to the AGROWOOD project that developed a calculation tool which is available on their homepage (www.agrowood.de).

[1] http://www.naturalengland.org.uk/Images/ECShandbook3ed_tcm6-12242.pdf.
[2] http://www.forestserviceni.gov.uk/index/publications/forestry-grant-information.html. http://www.dardni.gov.uk/index/rural-development/rdp-campaign/rdp-campaign-development-funding-schemes-and-programmes/rdp-campaign-development-farming/rdp_campaign-short_rotation_coppice.html.
[3] http://www.scotland.gov.uk/Topics/farmingrural/SRDP/RuralPriorities




:: COST-CALCULATION OF SRF ACCORDING TO HOFMANN (2010)

The following calculation shows how to calculate the costs of a SRF plantation for comparison with annual crops. The calculation is based on German circumstances and, therefore, with a fully mechanized harvesting method. In Table 12 the basic values for calculating the SRF are determined; in Table 13 the yield niveau is important to consider in the costs of harvest; Table 14 shows the possible capital for different scenarios. According to Table 14, the minimum price which needs to be paid for a yield of about 10 $t_{adry(ha*a)}$ is 65 €/$t_{adry(ha*a)}$. This can be seen as a borderline from where a SRF begins to become beneficial from an economic point of view.

Table 12: Basic assumptions for a cost calculation for SRF with hybrid poplar.

PARAMETER	UNIT	NUMBER
Time of cultivation	years	24
Rotation	years	3
Number of harvests	---	8
Yield niveau 1	$t_{adry(ha*a)}$	10
Yield niveau 2	$t_{adry(ha*a)}$	12
Yield niveau 3	$t_{adry(ha*a)}$	14
Plants	numbers/ha	10000
Rate of interest	%	5
Loss of harvest	%	6

Table 13: Capitalized value for different yield niveaus depending on market prices.

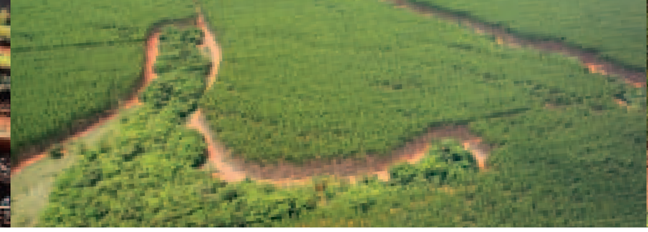
PRICES (€/t absolute dry mass)	YIELD NIVEAU (t absolute dry mass per ha * a)		
	10	12	14
60	-30 €	33 €	96 €
65	17 €	89 €	162 €
70	64 €	146 €	227 €

Table 14: Cost calculation for three different yield scenarios.

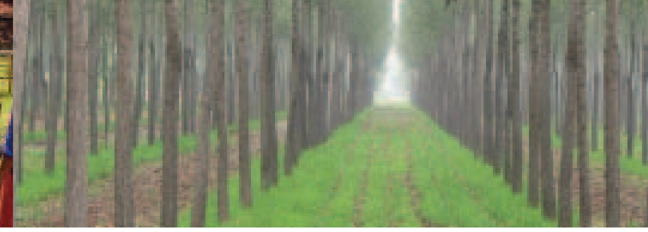
		IN TOTAL (€/ha)	AVERAGE/YEAR (€/ha)
Cultivation			
Greenwaste land herbicide application (21 m)		16.00 €	0.67 €
Cost of (Glyphosphat)		26.00 €	1.08 €
Autumn ploughing		107.00 €	4.46 €
Rotary harrow		46.00 €	1.92 €
Cost of area cultivation		**195.00** €	**8.13** €
Planting			
Planting material	0.15 €	1500.00 €	62.50 €
Planting machine costs	220.00 €	220.00 €	9.17 €
Time capacity for planting	1.5		
Labor capacity	4		
Price for 1h labor	6.50 €		
Costs of labor		39.00 €	1.63 €
Tractor costs incl. driver/ha	35.00 €		
Tractor costs incl. driver/ha		52.50 €	2.19 €
Costs of planting		**1811.50** €	**75.48** €
Maintenance			
Herbicide spraying (1 x soil herbicide, 1 x afterwards)	2		
Spraying 21 m (2 process organisation)	16.00 €	32.00 €	1.33 €
Bacara (1 l/ha)	60.00 €	60.00 €	2.50 €
Lontrel (2 l/ha)	75.00 €	150.00 €	6.25 €
Costs of maintenance		**242.00** €	**10.08** €
Σ cultivation & maintenance		2248.50 €	93.69 €
Σ cultivation & maintenance payment of interest about 24 years		**7251.64** €	**302.15** €
Harvest and transport (production niveau I)			
Chipper Claas (15 €/t dry mass)	15.00 €	3600.00 €	150.00 €
Area logistics and transport (10 €/t dry mass)	10.00 €	2400.00 €	100.00 €
Total costs of harvest I		**6000.00** €	**250.00** €
Harvest and transport (production niveau II)			
Chipper Claas (15 €/t dry mass)	15.00 €	4320.00 €	180.00 €
Area logistic and transport (10 €/t dry mass)	10.00 €	2880.00 €	120.00 €
Total costs of harvest II		**7200.00** €	**300.00** €
Harvest and transport (production niveau III)			
Chipper Claas (15 €/t dry mass)	15.00 €	5040.00 €	210.00 €
Area logistics and transport (10 €/t dry mass)	10.00 €	3360.00 €	140.00 €
Total costs of harvest III		**8400.00** €	**350.00** €
Recirculation			
2 x milling and working with disc harrow	500.00 €	1000.00 €	41.67 €
Costs of recirculation		**1000.00** €	**41.67** €
Costs of procedure I		**9248.50** €	**385.35** €
Costs of procedure II		**10448.50** €	**435.35** €
Costs of procedure III		**11648.50** €	**485.35** €
Loss of interest rate through initial investment		**5003.14** €	**208.46** €
Total Costs I		**14251.64** €	**593.82** €
Total Costs II		**15451.64** €	**643.82** €
Total Costs III		**16651.64** €	**693.82** €

EUROPE

KENYA



INDIA



CHINA

:: PROFIT INFLUENCING FACTORS

Kröber *et al.* (2010) made 8000 simulation runs (Monte-Carlo-Simulation) with different scenarios. Such an exercise is necessary as a one-time calculation is not meaningful because it is impossible that all chosen determinations will occur and it can lead to a higher degree of uncertainty.

The Monte-Carlo-Simulation calculates the probable distribution of the annual profits and 8000 runs calculated an average profit of 80 € per year/hectare. It considers the probable costs, earnings and revenues for specific production sites in Saxony Germany. Kröber *et al.* (2010) mentions nine possible factors for increasing or decreasing profit; one of these factors is the fencing of plantation sites because high game populations reduce the average calculated profit.

The collapse of SRF plantations can be caused by fungi infestations, insects or extreme weather and if the clearing of a plantation happens much earlier than planned because of such events, the higher the impact on the average profit. A reduction of about two harvests reduces the average profit to 9 €/(ha*a). Whereas, an extension of the economic life of a SRF plantation to 30 years (two extra harvests) leads to an increase of the average profit to approximately 60 €/(ha*a).

The doubling of transport distances leads to increase of the cost of transport by the factor 1.77 (Pallas *et al.*, 2006). The average loss is 18 €/(ha*a) when taking this factor into account.

In Saxony (Germany), the State subsidises 30 % of cultivation costs if the investment volume is greater than 20000 €.

Any increase in price of wood products will result in a higher average profit and the probability of increasing prices is high at the moment due to the concurrent demand and usage of wood for energetic and material purposes.

COMPARISON BETWEEN ENERGETIC USE AND ANNUAL CROPS

Hofmann (2010) calculates product profitability of winter barley, winter wheat and rapeseed, and the annual calculation of SRF benefits makes it possible to compare the different types of production. SRF has a higher product profitability from the yield niveau with minimum 12 t/dry mass per year and per ha and a price from 65 €/t. Kröber *et al.* (2010) makes comparable calculations and SRF is given as a viable alternative to the agricultural production line. Importantly, both mentioned the need for these calculations before making any investment decisions.

ECONOMICS IN AN AGROFORESTRY CASE STUDY: ITALY

Mainly in the northern region of Italy, SRF sites have been established (Spinelli, 2010). Normally poplar plants are used because sites are suitable and the famers know these species well. The systems mainly differ within their rotation cycle which may reach from one to two years up to 10 to 12 years. Where on average the rotation cycle is between five to six years the overall trend reaches towards longer cycles, so that the product mix may become diversified with industrial wood.

Simple coppice systems are known as well (Coppini *et al.*, 2007). Additionally arboricultore techniques have been developed for biomass production (Buresti *et al.*, 2003). The cultivation follows geometrical figures, examples of 'arboricultora' may introduce: *Quercus cerris* (Ce), *Castanea sativa* (Ca), *Alnus cordata* (O), *Prunus avium* (Ci) and *Quercus petraea* (R). Right side: planting *Populus ssp*, *Robinia pseudoacacia*, *Salix ssp.* (S), *Eucaliptus ssp.* and sometimes trees like *Prunus avium* (C) or *Junglas regia* (N) (Buresti *et al.*, 2003).

Nevertheless, Italy has a rich history of agroforestry production systems with worldwide traded fruits and nuts like olives and chestnuts. However, these traditional agroforestry sites are very costly and intensive in management, compared with other market prices their ROI is not competitive (Pardini, 2008). Nowadays the focus has changed towards sustainable agriculture for environmental protection and this may stand sometimes in contrast with the economic needs of the rural population, but, productive trees and agriculture systems have been re-established (Paris *et al.*, 2006).

KENYA

In Kenya, farmers do not receive any subsidies for tree planting and therefore grow them according to market demands and domestic necessity. However, there is no common or 'average' price the farmers can rely on and therefore the profit of a plantation remains uncertain until harvesting and selling. Despite this, it is possible to estimate the costs for farm labour which varies between 2.5 to 5 USD per day. For a profitability analysis case study from Western Kenya, see the associated BENWOOD report 'Profitability of Short Rotation Forestry from the Farmer's Perspective'.

INDIA

In India, SRF plantations do not receive subsidies and farmers grow their plantations according to market demand.

Subsidies to poorer sections of society are essential for their welfare in the developing world. Economists feel that these subsidies should be focused and very specific, otherwise they may encourage undeserving beneficiaries and increase the burden on the government and general public/tax payers. It has been emphasized that farmers should sell their produce at the right price instead of relying on subsidies for inputs like fertilizer, water and electricity, so that any benefits will flow to the intended and deserving people.

Although no subsidies are available for SRF, farmers can avail the subsidies that exist for crop production by inter-cultivating crops with fast growing trees (farm forestry/agroforestry).

Average prices for wood on the market depend on the type and purpose of the wood, but they currently stand at:

+ Pulp wood: Rs. 3500/– per ton on fresh weight basis
+ Timber wood: Rs. 5000/– per ton for ply wood on fresh weight basis
+ Fuel wood: Rs. 2000/– per ton on fresh weight basis at the site itself

District administrations decide the monthly rates for labour (current rate of Ludhiana district, Punjab is Rs 137 per day, equivalent to approx. 2.20 €), which are strictly followed in Govt. organizations, however, these rates do vary for private farm labour, which are normally higher than governmental rates. The situation of non-monetary payment to workers is negligible.

CHINA

In China, forestry does not only provide the necessary timber for economic development, but also plays an important role in safeguarding the environment, such as sand fixation, preventing soil erosion, CO_2 absorption and so on. The present stage of China's economic development is still facing the depletion of natural resources, mostly based on over-consumption and environmental damage. Its ability for sustainable development lies in the common development of economics, natural resources and environment. In recent years, China has developed a series of policies to encourage socio-economic sustainable development and the forestry policy provides forestry production subsidies, to support increasing forest cover and returning farmland to forestland. Although SRF has developed rapidly and has quite a broad market demand, it still relies on governmental subsidies.

Generally, there are three different types of subsidy available for SRF in China, mainly generated by specific projects:

+ National protection forest system construction project mainly supports SRF production in coastal and river areas; subsidized at 1493 yuan per ha
+ National forest and seedling project mainly supports national and provincial forest seedling demonstrations and improved varieties breeding centres; subsidized at 1.5 million yuan per project
+ National financial discount interest for forestry loan projects mainly grant four types of loans. The discount rate ranges from 1.5 to 6.0 percent, with a period not exceeding 3 years

However, the profit of SRF/AF systems still depends on the market price for wood. This price depends on type and purpose of the wood, with prices currently standing at:

+ Ordinary pulp wood: 1.500 yuan per m^3
+ Ordinary timber wood: 3.500 yuan per m^3
+ Ordinary fuel wood: 290 to 320 yuan per m^3

Besides the market price, labour costs are an important factor to consider when estimating benefits from SRF/AF systems. District administration decides the monthly rates (rates increased by around 17.5 % from 560 yuan per month in 2003 to 658 yuan per month in 2005) in rural areas, which are strictly followed in Govt. organizations. However, these rates vary for farm labour and they are normally higher than Government rates because accommodation and food is also provided. However, the average income of forest workers is still at a low level and tends to be less than half of the average income of workers in the urban areas.

Financial analyses and details about the national forest financial status are available at the responsible ministries.

BRAZIL

The establishment of tree plantations requires high investment. Although the productivity of eucalyptus plantations in Brazil is currently considered as one of the best in the world, the first harvesting period for most economic uses, including charcoal, cannot occur before the 7th year within a plantation cycle of up to 28 years. Thus, industries that are based on wood plantations have no income until full maturity of the trees, which is reached after seven years of growth. In order to cope with the intrinsic characteristics of this industry, loans must have at least a seven year grace period and a minimum duration of about 10 years which is almost non-existent in the Brazilian financial market and in most developing countries.

Most private banks, and even the Brazilian Development Bank (BNDES), which is the main source of long-term funding in the country and is a major alternative for these producers, cannot meet the sector's debt financing needs. Four out of the five long-term forestry loans offered by the Bank have duration of five years or less. Some funds available to forestry plantations are exclusively devoted to small-scale enterprises (i.e. BNDES Pronaf – for rural households only, and BNDES Propflora) or are only dedicated to the pulp and paper industry.

The Propflora facility has been created to support the implementation of plantation activities. However, it is capped at R$ 150 000, which is negligible considering the investment requirements of large-scale plantations. Likewise, the location of plantation activity in the State of Minas Gerais also makes it ineligible for other sources of official funds including the special funds structured for the less developed regions of Brazil, which also lack sufficient resources (e.g. North, Centre-west and North-east regional funds) and exclude the project region.

In addition to scarcity of funding, most companies, including the project entity (Plantar), have serious difficulties in providing collaterals and loan warranties. The plantations per se are not accepted as collaterals or permanent real assets, which significantly limits access to debt resources. The severe shortage of debt-financing and the prevailing double-digit real interest rates in Brazil is not encouraging for investors and creating long-term assets.

In Brazil, investors have struggled with high real interest rates (the highest worldwide) sustained by the implementation of a strict monetary policy aimed at curbing inflation since the early 1990s. Integrated activities to supply charcoal-based iron production are particularly affected since they are mostly dependent on long-term credit availability.

Brazil holds the largest concentration of forests in proportion to its territory, covering 64.3 % (544 million hectares) of the land area. Tree plantations or silviculture practices represent only 0.9 % of the country's total forested area, the remaining 99.1 % being native vegetation (LEITE, 2003).

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Options for modification of the final 'product' of SRC/SRF plantations at place (field) to increase product value and allow e.g. transport to higher distances. Optimizing value chains (fuelwood, gasification?).
2. Independence from subsidies and/or options for improved funding.
3. Lower investment costs, lowering rotation retention of SRF, and alternatives to eucalyptus SRF, lowering financial risks. Economic risk assessment, e.g. regarding climate, economically viable options for multipurpose usage of wood.

4. Potentials of Agroforestry

Figure 36: Poplar and Turmeric in India. Source: PAU, 2006.

There are many well known classical agroforestry systems described in the literature (e.g. the Tumpangsari system, the worldwide practised Taungya system, the Jhum system). The FAO introduces the home gardening system[4] as an approach for fighting rural malnutrition and the United Nations believe that agroforestry may be one step towards reaching the UN Millennium Development Goals (MDGs) (Garrity, 2004). It has been found that agroforestry can affect biodiversity conservation and ecosystem services of soil protection/enrichment, improvement of air and water quality, and water conservation in positive ways (Jose, 2009). On former agricultural or degraded land it is a very effective tool for carbon sequestration and climate change mitigation due to the deep carbon storage from the tree root system (Nair, 2011). Additionally, it supports diversified food and nutrition security by providing products for additional income and domestic consumption, thereby, acting as a safety net system (Garrity *et al.*, 2010; Kebebew *et al.*, 2011). Studies show that agroforestry works at multiple scales. At the smaller scales, the impact may directly benefit local communities and households and the surrounding environment, while on the larger scales the impacts are felt nationally and globally.

There should be informed decision-making regarding the composition and practice of agroforestry systems. Dixon (1995) underlines that non-sustainable agroforestry systems show degradation potentials resulting in significant GHG emissions. This is especially true in forest conversion scenarios, where newly converted forests into silvopastoral systems have significant loss of labile C and N compounds to the atmosphere. Other critics of agroforestry have issues with the high number of introduced invasive tree species used, and emphasise the need for suitable seeds, tree nursing techniques, management knowledge and local acceptance. Sustainable agroforestry management should be managed with ecosystem services in mind and impacts on the land over space and time. Agroforestry techniques may be suitable at a site for one set of needs, but, due to the complex system of environmental interactions and human needs, it may be contradictory for another (Nair, 2011).

[4] http://www.fao.org/DOCREP/003/x3996e00. htm#TopOfPage

Agroforestry systems in Europe also have a long history. They range from subsidiary agricultural use up to intensively managed non-timber forest product (NTFP) systems within forests, and they have often contributed towards socio-economic and cultural development. Examples can be given as:

+ Spain: bark collection from *Quercus suber* (cork oak) influencing culture and shaping land management (Torres, 2010).
+ France: intensive truffle collection changing high value NTFP into managed agroforestry system (Bonet *et al.*, 2006).
+ Italy: forest pasture and coppice management (Coppini *et al.*, 2007).
+ Other traditional industries are now of little economic significance, e.g. the tinder industry using *Fomes fomentarius* (hoof fungus), pine resin collection, willow weaving for traditional handcrafts, living fences or wind shelters.

Several different agroforestry systems are known in Austria and have prevailed in some areas of Germany, for instance: the use of fruit trees; hedges as living fences and sheltering against wind (Deim *et al.*, 2010); the use of trees as a landscape element within Austria's agri-environmental program (ÖPUL, 2007); for firewood production; using leaves as fodder; silvopastoral (e.g. integration of Christmas tree plantations and sheep) and silvoarable management (Oliveira, 2009). Over the last decades, farms with multipurpose agroforestry systems are increasingly used by city dwellers for recreational purposes (Deim *et al.*, 2010). Agroforestry is of little importance in Europe, but if applied it is highly diverse in its combining of forest, agriculture and livestock in one area (Stockinger *et al.*, 2001). In Germany, forestry and agriculture are generally strictly separated, with some exceptions in mountainous areas in the south of Germany (Luick *et al.*, 2008).

However, agroforestry has a great importance in other countries like India. Environmental sustainability and meeting social and economic objectives are identified to be important (Lal, 2004). Main aspects of research focus towards sound management of farm resources and optimal farm productivity, reduction of degradation and improvement of environmental quality, life of small and rural farmers and above all to maintain sustainability in farm production and long-term productivity (Chauhan and Ritu, 2005).

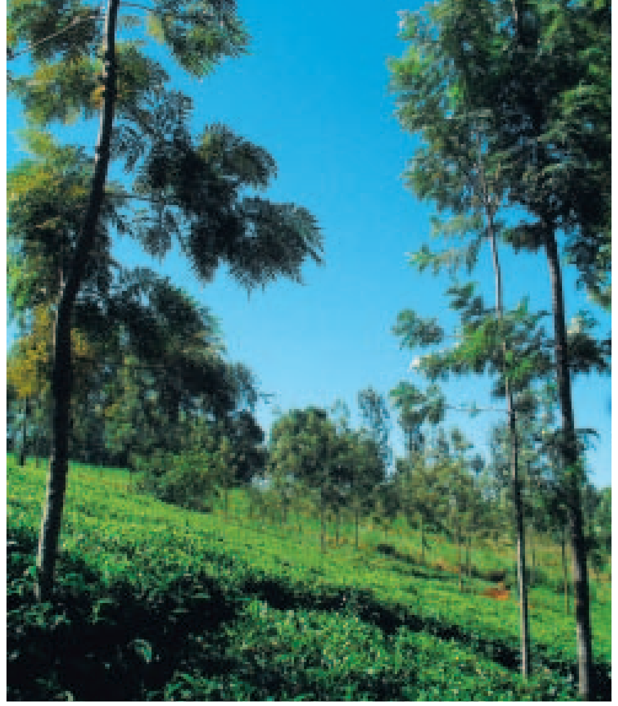


Figure 37: Grevillea and tea in Kenya. Genevieve Lamond, 2011.

Figure 38: Poplar and mushrooms in China. Marco Lange, 2010.

These examples show that on the one hand the functions and services that agroforestry systems can provide stay more or less constant, while, on the other hand, agroforestry products follow changing product costs and market prices depending on their substitution and popularity.

Nowadays, there is a highly emotive discussion field regarding the priority of food or energy production on agricultural landscapes, and this involves trees on farmland whether solely as SRF plantations or integrated with crops and/or livestock within agroforestry systems. As human populations, prices for land, food and energy rise globally, there becomes increasing competition for resources.

With stringent certification, changing product value appreciation of consumers, and advanced producer management towards more ecological and sustainable production schemes may have some balancing effects (Blackman *et al.*, 2009). Their political will and purchase decision may contribute towards supporting global climate change mitigation processes, fighting global biodiversity loss, supporting fair trade and/or promoting local energy autarchy as superior value. But such global challenges do need to be met with bigger and more workable solutions. One method might be changed land use and land management towards more sustainable and integrative production of biomass for energy supply and food within cost effective SRF systems. Combined production systems could be an option for transferring intensive agricultural production into a more flexible and less risky production of food and biomass using the third dimension of tree growth and their potentially favourable ecosystem impacts. However, the acceptance of such management options by farmers and energy crop producers, normally concentrating on classical energy crops like maize, palm oil or sugar cane, plays an important role. It could be promoted via locally established case studies and pushed forward by political will. Historical energy production systems like coppicing up to modern SRF, e.g. within alley cropping systems, become a serious alternative for energy production with comparably positive impacts on food production.

THE FUTURE OF AGROFORESTRY

Biomass often gets described as stored solar energy in organic matter. In the case of biomass, the closed carbon cycle is the focus of interest because it causes no direct net increase in CO_2 emissions to the atmosphere. However, at the moment, biomass production is still dependant on conventional energy sources, whether it is for transportation, production of fertilizers, or during soil preparation and harvest. Efficiency and sustainability criteria within production management, CO_2 neutral transportation and energy production efficiency have to be further adapted and applied. Furthermore, biomass production techniques have to be adjusted towards modern fuel and firing technology and effective logistic chains. This indicates that there is still important research to be carried out on SRF for optimizing the production process and output. In this regard important discussion fields are 1) food vs. fuel and technical optimization 2) compliance of minimum social standards 3) protection of natural environments and biodiversity, as well as 4) sustainability in agriculture, forestry and social frameworks.

Whilst agroforestry is mainly practised in emerging and developing countries for food, timber, firewood, mitigation towards global change impacts and soil protection, in European regions the discussions focus more on industrial bioenergy alternatives, biodiversity stepping stones for biotope networks and as an option for carbon sinks. From the global perspective, agroforestry appears in many topical discussions which serve to encourage this production system worldwide. Agroforestry practices can contribute towards the Reduced Emissions from Deforestation and Forest Degradation (REDD (+)) and The Economics of Ecosystems and Biodiversity (TEEB[5]); it is an option for CDM and JI projects; it provides renewable firewood and timber supplies for rural areas and optional NTFPs, as well as a number of additional ecosystem services (World Agroforestry Centre, 2009 b; Carmenza *et al.*, 2005; CGIAR, 2011).

FIELD OF FURTHER RESEARCH

Major research questions posed by project partners:

1. Domestication, utilization and conservation of superior agroforestry germplasm. Screening crop varieties, species, spacing etc.
2. What are the ecological/economic/social implications? How to establish knowledge transfer to rural farmers?
3. Management of agroforestry within SRF systems; management of eucalyptus agroforestry systems (climate, soil, phytotoxins management). Beyond that: ecological optimizations like root competition, DBH, density, LAI, canopy spread etc.

[5] http://www.teebweb.org

5. Socio-ethical Issues

Environmental responsibility is increasingly important for people globally and becomes reflected within the emotive 'food or cash crop first' discussion and emerging fears about the expected changes of landscapes into 'bioenergy landscapes' – observable in the case of SRF plantations (Figure 39). The aim is to find balanced and practical guidance for good and considerate decision-making. In SRF the focus is often set towards good management, sustainable practices and ecological or socio-economic sound decisions. Beyond that, the main ethical questions within the scope of biomass production are the following: what is a valuable landscape and how can it be appropriately used for food production as well as for renewable energy production? How to define ethically sound production? How to sustain food and energy production within economic, social and ecological dimensions? How to fulfil social responsibilities at the global scale and address unbalanced markets for energy and food production?

Figure 39: The 'Green Belt' open and extensively used landscapes at the former FRG/GDR border, Herbigshagen, Germany. Source: Torsten Sprenger, 2010.

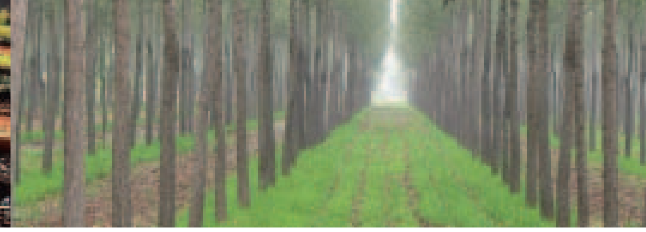
Despite all given answers for questions such as these, it is unlikely that there will be a correct or good answer for all conceivable situations. In fact, with a growing number of stakeholders involved we are facing a growing number of dilemmas and it becomes harder to compromise in a way that will satisfy everyone. For example, it might be viable for a small-scale subsistence farmer to use traditional agroforestry on his land, but facing a globally rising population there will be pressure on other producers to intensify food production perhaps using less sustainable methods. The question is how to act in this world and how to clearly differentiate between a right and wrong decision. That is the point where moral or philosophical evaluations according to different stakeholder views (and ethics) should be summarized and understood for future decision-making. This is a research area where the humanities and natural science should combine their knowledge and models much more closely than is currently the case.

But ethical considerations alone are not the answer for making overall good decisions. It is more a basis for moral discussions and evaluations, fundamental for understanding decision-making around a complex subject; as Nissing declares, *'ethic is the practical theory for moral decision making'* (Nissing, 2009). To differentiate whether a decision is morally good or bad it has to be evaluated against the ethical theory or standards behind it. The theory or standards may be based on different ethical foundations concerning religion, culture, formulated philosophy or describable practical- social experiences from an individual person.

It becomes obvious that the wish for ethics in agriculture, forestry, or in this case SRF, has much to do with the wish for a basic agreement or understanding of the ethical norms from involved stakeholders based on their needs, experiences, laws and culture. Here is the descriptive melting point where biomass production on agricultural landscapes takes the needs of stakeholders, ecological and scientific findings, as well as socio-economic forces seriously.







The growing need for ethical considerations indicates a rising disproportion between things we know and the 'blackbox' we believe that we do not know. Practical ethics have to take into consideration technical questions as well as social or superordinated interdisciplinary questions, for example: what will the landscape look like if we have an increasing amount of biogas or wood heated power plants? What happens with biodiversity under a maize regime? Is agroforestry the better option? How will people feel about recreation or quality of life within energy landscapes? What is the impact of these feelings and how to manage non-marketable values within traditional markets? In fact, practical ethics requires a good understanding of prior defined normative ethics as it gets described within authorities of laws, religion or cultures (Spaemann, 2006) or even standardized best practices.

Science is structured to focus research, quantifying objective results, trying to understand simplified but practical models and is functionally separated into different subjects to handle complexity within definable parameters. These are practical approaches to handle complexity. However, the area of ethics challenges the above point of view and would require interaction between natural sciences and humanities for a proper understanding.

IMPORTANCE OF ETHICS

The production of biomass from SRF, whether observed from a forestry or agricultural point of view, basically follows economic trends. A basic dissonance is often seen within market values and intrinsic values of the resource. Furthermore, these intrinsic values are usually not easily replaceable, for instance, a beautiful scene or a personal relationship towards a home area is very important and cannot be exchanged. The challenge is to picture the intrinsic values reflecting an ethical standard to make these intrinsic and maybe subjective values comprehensible. Realistically there are no hard exchange values e.g. comparing the beauty of landscapes to food or cash crops. However, ethics or ethical evaluations are often used as vehicles to weight 'good values' against each other. This fundamental judgement of right or wrong or higher or less values is often based on argumentation and visibility of argumentation, but may be in contradiction to balanced decision-making between generally accepted values and options.

Quantitative science is able to give us more or less statistical sound and precise information about, for example, landscape changes and measurable relations for justified decision-making. We are also able to quantify biodiversity indicators or economic feedbacks and with high effort it is possible to determine material or energy flows of SRF plantations. We can get information about social and political frameworks via interviews or questionnaires, which can determine policies and legislations. Psychology is able to identify reasons for decision-making, e.g. decisions of agricultural land owners may often be guided by their own experiments and cultural or personal experiences than from new scientific or new positive economic results (Kröber *et al.*, 2010, Pretzsch et al 2010). And qualitative approaches, often carried out by the humanities, are able to describe situations and reasons of individual acting. But many values and feelings cannot be described sufficiently (Figure 40).

So what makes ethics so important? On the one hand we certainly need ongoing discussions about and structuring of normative terms like 'sustainability' or 'beauty of landscapes'. Their definition seems to be endless, but their usage is fundamental and reaches far into everyday praxis. Under the title of 'sustainability', agricultural and forest economies try to optimize yield and outputs. But sustainability itself as a fundamental economic concept has experienced a continuous extension of relevance and sense since its first 'modern' and economic definition by Carlowitz in 1713. The German Federal Nature Conservation Act determines to protect landscapes (§23 (1) .3) 'because of their rarity, special character or outstanding beauty' (translated from the original German text: 'wegen ihrer Seltenheit, besonderen Eigenart oder hervorragenden Schönheit'). Normative terms tend to be continuously defined and applied to very different contexts which can lead to misunderstandings and misconceptions, especially within international frameworks and communities with very different backgrounds. For example, in Europe there are five different forest cultures identified (Bell *et al.*, 2005) and these cultures define the basic principles of forest management slightly differently, which indicates different normative ethics behind it. However, when discussions or papers use such terms, basic concepts are often clearly defined and commonly agreed but may individually draw distorted pictures of compliance.

Another view within the framework of ethics determines culture and its relation towards personal aspects. It influences how decisions are made, it combines legislation and policies, structures life aims and personality because of a basic compliance towards ethical standards and moral decisions about what is felt to be right or wrong. This encloses social behaviour in concrete forms, for example, the willingness for interaction regarding what is right or wrong.

A third already mentioned aspect relates towards a more and more complex world, whether in a sense of scientific work, human development or ecological interactions. This will ultimately result in increasingly more complex answers and management rules. A difficulty found in complex forest management is that the focus is not set towards a specialized product, service or function which would make it easier to handle. Management of complex systems

is limited by resources, understanding of complexity and possible contrary product production, maintenance or interaction. This can lead to economically sub-optimal results. Thus, it shows that the decision-making process is not only objective based on numbers and rules, but also within the evaluation of, for example, non-economic products, functions or services and their value.

The fourth aspect draws back to the definition of ethics as a theoretical approach towards moral decisions; it comprises discussion about right or wrong decisions. In this case, philosophical ethics uses all available practical and theoretical information about bioenergy, from the natural sciences as well as the humanities, to compare with other conventional energy resources and provides a theoretical foundation for decision-making.

Overall, ethics about agriculture or forestry can be seen as a minor branch of applied bioethics. This means that ethics about SRF is already part of an ethical framework with long traditional and cultural backgrounds; for example, when discussions arise about genetically modified plants there are many existing resources and arguments already known in agricultural praxis which would also be applicable within the areas of forestry and SRF.

Besides scientific or political use of ethics for discussion and good or consensual decision-making, its practical use should be applied when designing best practices and as reflection for policies or social concerns. This could form a basis for standardization and certifying agencies, which may guarantee a common ethic of production and use of resource.

Figure 40: Grave yard in Ghana in the middle of the forest. Source: Thomas Friedrich, 2010.

6. Carbon Credits in Short Rotation Forestry and Agroforestry

CDM projects create emission permits that are used by industrialized countries to show they are meeting commitments of reducing their greenhouse gas emissions, as agreed under the Kyoto Protocol (Dutschke and Schlamadinger, 2003). The emission permits, which are in the form of 'carbon credits' and sold on 'carbon markets', were intended to meet compliance targets; however, a private market containing NGOs, big business and investors, developed over the years. To realize a sustainable and satisfactory facilitation of emission reduction, the protocol provides different schemes and standards which generally can be divided into a **regulatory** and **voluntary** market (Table 15).

At the moment 27 A/R CDM projects exist in the world (see Annex). Carbon credits of A/R CDM projects are currently not allowed to be used in the regulatory market because of the insecure permance (see below).

The general principles and background of trading on carbon markets are explained concisely by Chaudhry (2008):

'[...] In order to understand carbon markets, it is essential to differentiate between the two types of commodities used in carbon trading, allowances and offsets. Allowances are generated by the cap-and-trade system while offsets or carbon credits are generated by baseline-and-credit systems.

In a cap-and-trade system each of the participants is assigned a fixed number of allowances based on the emission reduction targets (usually carried out by political negotiation) which only be traded amongst the participants. Participants that reduce emissions beyond what they were assigned are left with excess allowances while those participants which have not met their targets are left in need of the same. This demand and supply facilitates a market system and determines prices for the allowances. What is challenging is that the caps set have to be stringent enough to bring about an effective level of change while not so high that the price sky-rockets (due to inelastic supply) when the participants fail to meet the targets. On the other hand in a baseline-and-credit system more credits are generated with each new project that is implemented [...]'.

Table 15: Opportunities to facilitate carbon emissions / credits on the carbon market.

CARBON MARKET	CARBON CREDITS
REGULATORY MARKET	**European Allowances (EUAs)** EU Emission Trading System (EU ETS)
	Certified Emission Reductions (CERs) Clean Development Mechanism (CDM)
	Emission Reduction Units (ERUs) Joint Implementation (JI)
VOLUNTARY MARKET	**Verified Emission Reductions (VERs)** Gold Standard; CarbonFix Standard; Climate, Community and Biodiversity Standard; Voluntary Carbon Standard; etc.

THE REGULATORY MARKET

Under the Kyoto Protocol, industrialized countries and Annex I countries agreed to limit and reduce their greenhouse gas emissions. Non-Annex I countries are not obliged to reduce emissions as yet, but they can take part within the CDM initiatives. They may be asked to take more active measures to reduce emissions in the future.

The Kyoto Protocol provides three main strategies that may be applied in order to facilitate reductions in emissions:

Figure 41: Sprouting Source: Martin Hofmann, 2007.

:: EUROPEAN UNION EMISSION TRADING SCHEME (EU ETS)

In 2005, the world's first large-scale CO_2 emissions trading program, the EU ETS, began operating. Despite the long time that it took for some of the twenty-five member states of the EU to allocate emissions permits – or allowances (EUAs) – and to implement the electronic registries that would enable trading, a quantitative limit on CO_2 emissions was imposed and since then, a market price has been paid for CO_2 emissions by virtually all stationery, industrial, and electricity-generating installations within the EU (Ellermann and Buchner, 2007). Currently, the five sectors covered by the scheme are electricity generation, pulp and paper, oil refineries, building materials and ferrous materials; aviation will also be on board the scheme post-2012 (Chaudhry, 2008).

:: CLEAN DEVELOPMENT MECHANISM (CDM)

Under the CDM, Annex I countries invest in GHG reduction projects in Non-Annex I countries as a substitute for reducing their own emissions which could be more expensive and unviable to undertake themselves (Chaudhry, 2008). If the host country approves the project and it meets the CDM criteria, investors get Certified Emission Reductions (CERs).

:: JOINT IMPLEMENTATION (JI)

Joint Implementation is comparable with the CDM, but GHG reduction projects are originated and performed between Annex I countries in order to generate Emission Reduction Units (ERUs) used for compliance purposes.

The different types of carbon credits generated by the available mechanisms are:

(1) EU-Allowances (EUAs) are provided by the EU member States within EU ETS. According to Strasdas *et al.* (2010) they have good credibility, however it is not ensured that the so-called ton/years approach (Moura Costa, 1996; Moura Costa and Wilson, 2000) is reached after decommissioning.

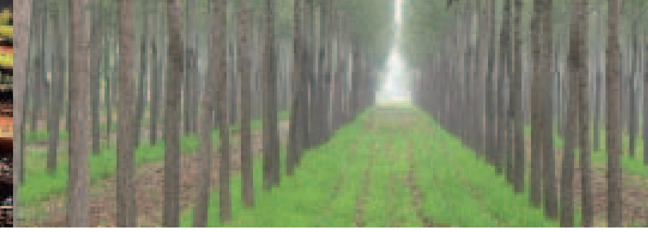
(2) Certified Emissions Reductions (CERs) are generated within CDM projects. CERs have high credibility as they are certified by the UN via independet auditors (Designated Operational Entities (DOEs)). However, it is evident that many CDM projects are large scale industrial projects disregarding sustainable development. Furthermore, the 'additionality' criterion (see below) is not continuously ensured (Strasdas *et al.*, 2010).

(3) Emission Reduction Units (ERUs) are generated within Joint Implementation projects. ERUs are also certified by certain DOEs and registered by the UN and have high credibility.

(4) Removal Units (RMUs) are carbon credits for national activities regarding carbon sinks. According to the Kyoto Protocol, the countries may generate carbon credits when saving GHG emissions by way of 'sinks' through afforestation and reforestation activities. The RMUs are registered like the ERUs and CERs and are comparatively trustworthy.







To guarantee integrity of CDM/JI projects the UNFCCC defined five criteria that have to be met in order to qualify (CDM Audio Files on DVD):

:: ADDITIONALITY

Climate protection projects have to show additional emission reductions which would not be realized without the existence of that project. Chaudhry (2008) gives an excellent definition which clarifies this criterion: '*[...] Additionality seems like a fairly simple concept: An activity is additional if it would have not occurred with the 'business-as-usual' scenario. In other words, if the project would have happened anyway, the project is not additional. Additionality makes intuitive sense: for example, if a person buys carbon offsets to 'neutralize' the emissions from his car, he can still drive his car in exchange for paying someone to reduce their emissions in his place. If the person buys the offsets from someone who would have reduced their emissions anyway, regardless of the payment, in effect the person has not neutralized his emissions but merely subsidized an activity that would have happened anyway. Additionality is thus an essential element needed to ensure the integrity of any baseline-and-credit scheme. However, additionality is very difficult to determine in practice. [...]*'

To test the 'additionality' of a project, the difference between the baseline and the project's emissions is evaluated. The **baseline** describes the reference scenario, determining the amount of GHG emissions which would have been produced without the project. Therefore, baselines are essential when evaluating emissions reductions in climate protection projects (BMU, 2010).

:: PERMANENCE

GHG emission reductions should be permanent. Permanence measures how long an afforestation and/reforestation project will be able to sequester carbon in spite of risks of destruction by fire, pests, illegal logging etc. (Chaudhry, 2008).

:: VALIDATION, VERIFICATION, CERTIFICATION

Independent third parties control the verification stage; this is when they verify the calculated GHG reductions in the present and future phases of a project.

:: LEAKAGE

Any GHG reduction implemented by a project should not cause emissions elsewhere. Leakage can be described as a project's unintended effects on GHG emissions outside the project boundaries (Chaudhry, 2008).

:: DOUBLE COUNTING

Double counting is when the same emission reductions are accounted for more than once; this should not happen within a project.

According to the UNFCCC (2011), there are different types of projects that may be applied in order to generate carbon credits:

- Renewables: generation of solar and wind energy, biomass, hydropower, geothermal energy and/or wave or tidal energy
- Technical and organizational measures that increase the energy efficiency at consumer and producer level
- Sinks/sequestration: capture, storage and binding of carbon through application of certain techniques and measures

THE VOLUNTARY MARKET

The voluntary market is where companies, NGOs, governments and individuals can purchase carbon credits for purposes other than meeting compliance targets (Chaudhry, 2008). Thus, the retail market refers to companies and organisations that invest in offset projects and then sell off portions of the emission reductions in relatively small quantities with a mark-up (Taiyab, 2006).

However, the voluntary carbon market is often called a 'buyer-beware' market as it is an unrestricted version of the regulatory market and consequently faces a lot of criticism with regards to the quality and 'additionality' of the offsets traded (Chaudhry, 2008).

The voluntary market established several standards, but some have low credibility as they do not match the criteria of the Kyoto protocol and the regulatory market. Among the different standards on the voluntary market, the Gold Standard has proven to be the most credible one.

The Gold Standard (GS) was published in 2006 and is accepted and supported by the UNFCCC and more than 60 NGOs. The main objective of the Gold Standard is to ensure a sustainable development in host countries with special focus on the criterion 'Additionalty' (Gold Standard, 2011). However, to secure the UNFCCC criterias for CDM, the Gold Standard just validates projects regarding renewable energy and energy efficiency. According to Strasdas *et al.* (2011), carbon credits with the annex 'Gold Standard' increase their market value.

Important standards on the voluntary market to be aware of for A/R projects are:

+ **CarbonFix Standard**
+ **Climate, Community and Biodiversity Project Design Standard**
+ **Voluntary Carbon Standard**

In conclusion, carbon sequestered in developing countries' forests can offset carbon emitted in industrialized countries, which in turn may be beneficial for both parties, if the installed land use is protected in the long-term (Dutschke, 2001).

FIELD OF FURTHER RESEARCH

The 'Research Agenda' of the BENWOOD project primarily focused on issues surrounding SRF/agroforestry, CDM and climate change.

Many research questions were slanted towards the economic impact and justification of CDM and JI projects:

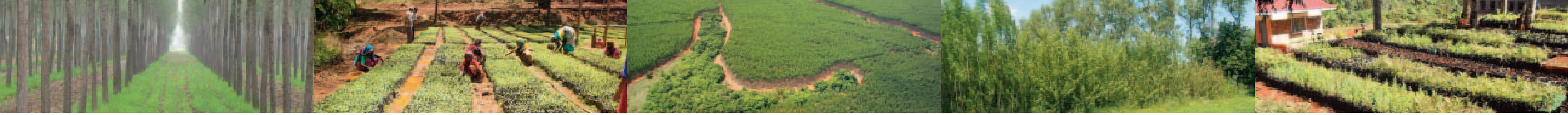
1. Identification of barriers of SRF adoption.
2. Economic valuation of ecosystem services.
3. Global/national trade models for carbon/timber/fuel market intelligence.
4. Evaluation of benefits of energy efficiency and bio-energy GHG mitigation, estimation of carbon stock of different SRF species.
5. Creation of inventory for existing carbon stocks and future projections.

Additional research areas were discussed in connection with the specific research areas of the BENWOOD consortium. Examples are as follows:

1. Research requirements on climate: species and management as well as interactions between climate change, biodiversity and landuse (Potsdam-Institut für Klimafolgenforschung, 2010).
2. Improving the ability of agro-ecosystems and governments to cope with climate change.
3. Climate change and its impact on management seasons, options for CDM countries (e.g. plant selection).

CONCLUDING REMARKS

In essence, the BENWOOD project has served to enable communication and dialogue about short rotation forestry and agroforestry practices across Europe, China, Brazil, India and Kenya. With the potential carbon sequestering ability of trees and their impact on livelihoods across the globe, this research has taken place within a framework of the Clean Development Mechanism. There is still much to learn about the tree species used within SRF and agroforestry systems across the partner countries, but we hope that our findings will provoke further research into these areas and encourage those who are implementing projects to take into consideration all the important issues that have been covered in this document.



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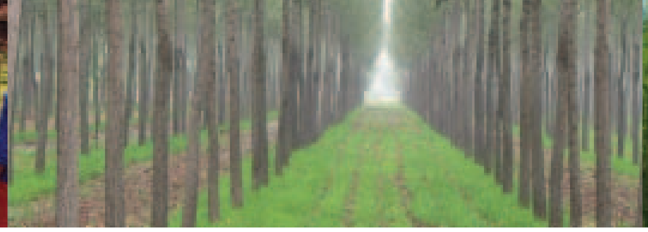


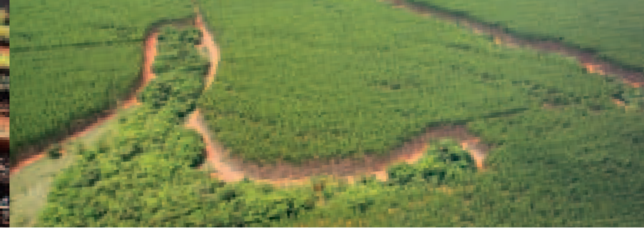

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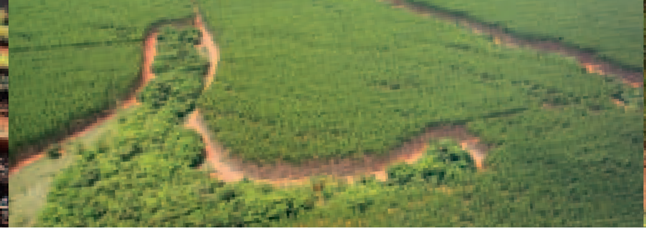

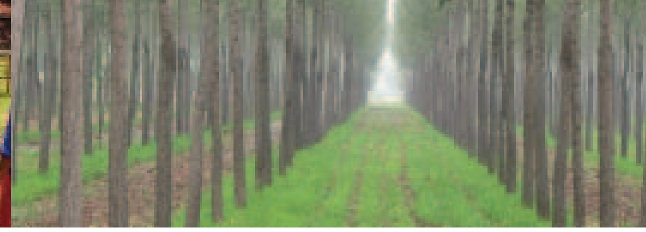
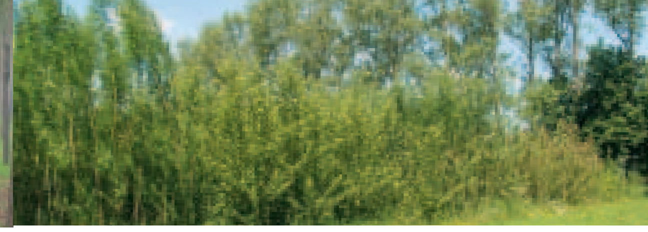

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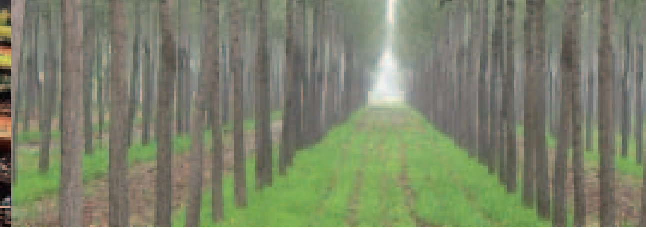

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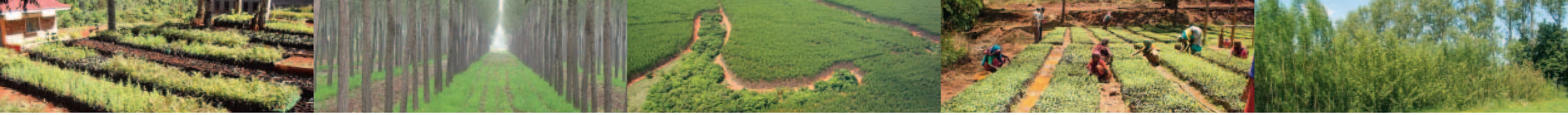

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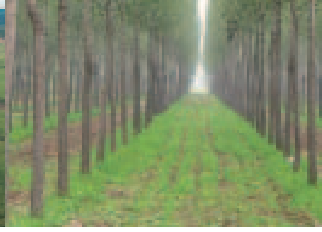
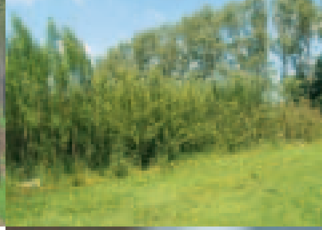
Annex

Table 16: Registered afforestation/reforestation CDM projects. Source: UNFCCC, 2011.

REGISTERED	TITLE	HOST PARTIE	METHODOLOGY *	REDUCTIONS **
10 Nov 06	Facilitating Reforestation for Guangxi Watershed Management in Pearl River Basin	China	AR-AM0001 ver. 2	25.795
30 Jan 09	Moldova Soil Conservation Project	Republic of Moldova	AR-AM0002	179.242
23 Mar 09	Small Scale Cooperative Afforestation CDM Pilot Project Activity on Private Lands Affected by Shifting Sand Dunes in Sirsa, Haryana	India	AR-AMS0001 ver. 4	11.596
28 Apr 09	Cao Phong Reforestation Project	Viet Nam	AR-AMS0001 ver. 4	2.665
05 Jun 09	Reforestation of severely degraded landmass in Khammam District of Andhra Pradesh, India under ITC Social Forestry Project	India	AR-AM0001 ver. 2	57.792
11 Jun 09	Carbon Sequestration through Reforestation in the Bolivian Tropics by Smallholders "The Federación de Comunidades Agropecuarias de Rurrenabaque (FECAR)"	Bolivia	AR-AMS0001 ver. 4	4.341
21 Aug 09	Uganda Nile Basin Reforestation Project No.3	Uganda	AR-AMS0001 ver. 5	5.564
06 Sep 09	Reforestation of croplands and grasslands in low income communities of Paraguarí Department, Paraguay	Paraguay	AR-AMS0001 ver. 4	1.523
16 Nov 09	Afforestation and Reforestation on Degraded Lands in Northwest Sichuan, China	China	AR-AM0003 ver. 3	23.030
16 Nov 09	Reforestation, sustainable production and carbon sequestration project in José Ignacio Távara´s dry forest, Piura, Peru	Peru	AR-AM0003 ver. 4	48.689
07 Dec 09	Humbo Ethiopia Assisted Natural Regeneration Project	Ethiopia	AR-AM0003 ver. 4	29.343
02 Jan 10	Assisted Natural Regeneration of Degraded Lands in Albania	Albania	AR-AM0003 ver. 4	22.964
15 Jan 10	The International Small Group and Tree Planting Program (TIST), Tamil Nadu, India	India	AR-AMS0001 ver. 5	3.594
16 Apr 10	Forestry Project for the Basin of the Chinchiná River, an Environmental and Productive Alternative for the City and the Region	Colombia	AR-AM0004 ver. 3	37.783
27 May 10	Nerquihue Small-Scale CDM Afforestation Project using Mycorrhizal Inoculation in Chile	Chile	AR-AMS0001 ver. 5	9.292
21 Jul 10	Reforestation as Renewable Source of Wood Supplies for Industrial Use in Brazil	Brazil	AR-AM0005 ver. 2	75.783
15 Sep 10	Reforestation on Degraded Lands in Northwest Guangxi	China	AR-ACM0001 ver. 3	87.308
03 Dec 10	'Posco Uruguay' afforestation on degraded extensive	Uruguay	AR-ACM0001 ver. 3	21.957
07 Jan 11	AES Tietê Afforestation/Reforestation Project in the State of São Paulo, Brazil	Brazil	AR-AM0010 ver. 4	157.635
11 Feb 11	Reforestation of grazing Lands in Santo Domingo, Argentina	Argentina	AR-AM0005 ver. 3	66.038
18 Feb 11	Ibi Batéké degraded savannah afforestation project for fuelwood production (Democratic Republic of Congo)	Democratic Republic of the Congo	AR-ACM0001 ver. 3	54.511
28 Feb 11	Improving Rural Livelihoods Through Carbon Sequestration By Adopting Environment Friendly Technology based Agroforestry Practices	India	AR-AM0004 ver. 3	4.896
04 Mar 11	India: Himachal Pradesh Reforestation Project – Improving	India	AR-ACM0001 ver. 3	41.400
04 Apr 11	Kachung Forest Project: Afforestation on Degraded Lands	Uganda	AR-AM0004 ver. 4	24.702
07 May 11	Southern Nicaragua CDM Reforestation Project	Nicaragua	AR-AMS0001 ver. 5	7.915
26 May 11	Forestry Project in Strategic Ecological Areas of the Colombian Caribbean Savannas	Colombia	AR-AM0005 ver. 3	66.652
11 Jun 11	Aberdare Range/Mt. Kenya Small Scale Reforestation Initiative Kamae-Kipipiri Small Scale A/R Project	Kenya	AR-AMS0001 ver. 5	8.542

* AM – Large scale, ACM – Consolidated Methodologies, AMS –- Small scale.
** Estimated emission reductions in metric tonnes of CO_2 equivalent per annum (as stated by the project participants).



The major project outputs can be found on the DVD attached to the brochure and/or can be downloaded from the public BENWOOD website on the following link: **www.benwood.eu.**