Final public international conference of the Benwood project

Conference proceedings

Short Rotation Forestry and Agroforestry: an Exchange of Experience between CDM Countries and Europe.

June 20 – 22, 2011

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Dear reader of this booklet,

one of the phenomenons which led to the fall of ancient cultures is what Pulitzer award winner 1998, Jared Diamond, calls 'forgetfulness about the landscape' in his book 'Collapse. How Societies Choose to Fail or Succeed' (Penguin. 2005). The population of the Easter Island deforested the terrain of their own island obviously not on purpose or with destructive intentions - it was because elder generations were not any more alive who would have been able to *pass on information* how much forest there was in former times and about its vital functions.

Today we have a chance to do better. The difference is our potential to *make information available* in due quality and language, first place in oral but as well in written form, in today's world also backed up with photographs and film material.

The Benwood project has been funded by the European Union within its research programme FP7 in order to make relevant information on short rotation forestry available to stakeholders bundling according resources. Benwood groups project partners from Africa (represented via the project partner from the U.K., based in Kenya), Austria, Brazil, China, Croatia, Germany, India, Italy, Poland, Sweden and the United Kingdom. This booklet is part of the overall information exchange campaign. At the corresponding final public conference in Italy participants from four different continents have come together to exchange experience on short rotation forestry and agroforestry.

In addition to exchanging knowledge across national borders, we have to talk to each other *across disciplines* in order to approach adequately current global challenges (climate change, food scarcity, mass introduction of renewable energy)

For instance, this becomes obvious when discussing about the *usage of wood*. In an integrative approach, in a project on short rotation forestry a project developer should dedicate the same attention to introducing cooking stoves with an improved efficiency as she/he dedicates to the design of the short rotation plantation itself and the optimization of the wood yield. Every kilogram of wood saved in combustion (reducing heat losses and not combusted parts) is equal in value to an additional kilogram of wood obtained from optimizing the wood plantation. Moreover, think about other disciplines such as photovoltaic systems for irrigation pumps, timber and pulp & paper industry etc.

Benwood tried to take account of the exchange between cultures and disciplines and provides according resources to stakeholders:

Written outputs:

Please download them from the public website www.benwood.eu soon after this conference (June 2011) - at least in draft form:

1. *Best Practices of Short Rotation Forestry* – a description of practices focusing on Short Rotation Forestry in Europe

2. *Land use management* standards – a description of the conflict between growing trees on agricultural fields and food production with a focus on African case studies
3. *Guidelines on Short Rotation Forestry* – a synthesis of the essentials of short rotation forestry for project developers
4. *Profitability of Short Rotation Forestry from the Farmer's Perspective* – a synopsis of differences between developing and industrialized countries together with case studies on different business models. Sheds light also on the economic importance of annual crops in agroforestry systems.
5. *Guideline for project developers: Information about cooking stoves* – an overview on the relevance of the efficiency of small cooking stoves based on wood fuel.
6. *Biomass gasification, options for local electricity and charcoal production from Short Rotation Forestry* – an document 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 countries which may host the so called 'CDM projects' with regard to short rotation forestry (traditionally these countries are developing countries)

Direct, personal contacts via public workshops

Since 2010 events of personal face-to-face exchange have taken place, This was in Beijing, three workshops/awareness camps were held in India one of which, sponsored as well by IUFRO, was the biggest event in the whole project with about 200 participants resulting in many scientific articles. Moreover, there was a virtual live seminar (in the internet) held in November 2010 with participants covering a geographical space between Brazil and India. And finally there is the event in Italy where the current booklet is a result of.

Films and photographs

A DVD has been produced and is available against a small fee to cover shipping cost. See details on how to obtain it at ww.benwood.eu. The DVD includes in particular all material too bulky for download, for instance about *2,5 hs of video material* and more than *2000 photographs*.

Let us not stop here

Please see this current booklet as your potential entry point to something that should go on after this project has ended,- the exchange of experience among stakeholders on short rotation forestry and agroforestry.

Means to continue the international exchange of experience are

1. *registering* at the website www.benwood.eu. This website will be soon integrated into the larger network 'Escorena' (http://www.escorena.net/) which has been initiated by the FAO (Food and Agriculture Organization of the United Nations). The www.benwood.eu website will be maintained on an honour basis with contents from an according working group on short rotation forestry.
2. *contacting* one of the Benwood country managers. You find them listed within the organizing committee at the beginning of this booklet. If you are not located in one of those countries contact me.
3. *looking elsewhere*: Benwood formally ends by August 2011, however please take note of other relevant international events such as the annual World Congress of Agroforestry which provides several hundred abstracts as well after each event for download to those who cannot attend.

Finally, I want to thank all of the *participants* who have taken the effort of coming to Italy and have assumed the burden of paying the flight ticket and all other auxiliary cost. Particularly this regards the *speakers and authors* (some of them could not come) who have provided their contributions to this booklet.

Since this booklet is published towards the end of the Benwood project let me express my thanks to the *Benwood project partners* who have managed to fill the project with good results coping with barriers in space, time, language and culture. Last but not least thanks to my colleague *Magdalena Chuda* who has worked hard to make this conference come true.

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MESSAGE

Millions people around the world depend directly on the goods and services provided by forests for their livelihood and in some cases even for their survival. Increasing demands for fuel, timber, fodder and other forest based resources are causing heavy pressure on the limited forest resources world-over in general and India in particular. The SRF species like poplar, eucalyptus, leucaena, robinia, willow, etc. have been found attractive due to their fast growth, adaptability on wide range of site conditions, acceptable marketing, etc., and have been found to reduce the pressure from the traditional forests. However, majority of fast growing species have extended beyond their geographical limits and thus have become a concern to environmentalists. Plantations of these species have raised a debate among the foresters and the environmentalists. Foresters maintain that SRF species are helping in meeting the increasing wood and other product demands. SRF plantations can serve as a substitute for fossil fuels thus reducing as such emission of greenhouse gases to the atmosphere. But, environmentalists oppose them because of negative ecological implications and stress that the water use efficiency, biodiversity depletion, nutrient harvesting, dendro-remediation, etc. are different areas of concern for generations in posterity.

*The BENWOOD project under the 7th framework program of European Commission promoting the exchange of experiences among the researchers and project developers in the area of Short Rotation Forestry was initiated during 2009 for comprehensive assessment of scientific information on fast growing tree production, adoption, management, marketing, investment, etc. The project during these two years emphasized to separate the fantasy from the facts on SRF. I am sure the short rotation forestry best practices, deliverables, research agenda, etc. will provide the adopters, managers, investors, policy makers, etc. with essential knowledge for enhanced adoption of SRF species. In the project, efforts have been made to seek the valuable inputs from different stakeholders in different partner countries to provides background information and future prospective. It was a great opportunity for me to work with experiences scientists from partner countries and my experiences will go a long way to shape my future research programme. The proposed workshop on "**Short Rotation Forestry and Agroforestry: an exchange of experience between CDM countries and Europe**" (June 20-22, 2011) has included diverse topics for the benefits of the stakeholders and it would be a useful input to improve upon the deliverables. I hope that significant recommendations will emerge from this three days workshop on SRF. I extend a warm welcome to all the participants for their support and encouragement. The efforts of Mr Thomas Lewis, Project Coordinator Benwood and Ms Magdalena Chuda, Project Assistant are praise worthy and I congratulate them and extend my best wishes for the success of BENWOOD workshop.*

With kind regards,

(Sanjeev K Chauhan)

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BJFU is the only institute involved in Benwood project"Coordination Actions in Support Of Sustainable and Eco-Efficient Short Rotation Forestry in CDM/JI Countries"in China, I am honored to participated in the whole process of the project as the man in charge.

China is a vast and populous country, the seventh national wide survey of forest resources indicated that: the overall area of woodland in China was 195,452,200 hectares, percentage of forest cover was about 20.36%, which was only account 2/3 of the global average; per capita forest area was 0.145 hectare, less than 1/4 of which of the rest of the world. In 2009, the consumption of wooden resources was 421,894,800 m^3, while the domestic supply was only 237,978,700 m^3, leaving a gap of approximately 1.8 billion m^3, the domestic supply is far from sufficient for the market, and the demand-supply contradiction stood out. In order to resolve the problem, Chinese government has been very supportive in developing SRF. The Benwood project would provide a uniformed standard for planting, growing, exploiting, and management of SRF, strengthen the communication path of experience between China and the rest members, facilitating the development of the entire industrial chain, which means significant for the growth of SRF in China.

During the project, the Benwood project research team from BJFU worked hard, has tried all their best to finish all the work, and held a mid-term meeting and seminar of Benwood project in Beijing-"international Workshop on Short Rotation Forestry Potential in Energy Utilization and Carbon Trade" in April, 2010. The achievement of the meeting was well recognized by all participants. I would like to express our sincere thanks for all the valuable support and help we received from all the partners.

I believed that the reason why this project was completed excellently, the followings are inseparable:

- A high performance team is the basis for the implementation of the project. The unity andcooperation among Benwood partners increased the efficiency and quality of the work;
- Specific goals and a sophisticated plan are the premise for the implementation of the project. Benwood project is with a detailed and careful planning in the prophase, and every work package contains all the corresponding tasks and expected results, there is also a detailed description of the tasks undertaken by each partners, at the same time, the leader of each task has a reasonable plan and arrangements for the relevant works, all of these established a foundation for the project being proceed as scheduled;
- Communication and executive ability are the guarantee for the implementation of the project. For the heavy workload and so many partners involved, the communication between all the members seems more important. Energieautark gmbh, headed by Thomas Lewis, established the website for Benwood project that provided a platform for members for information and resource sharing. In addition, the executive ability of partners has provided a safeguard for the project;

The final Benwood meeting will be held in Italy in June,2011, which can offer a platform for communication between the experts on SRF and Agroforestry in CDM countries and EU countries, I wish the best wishes for the success of this conference.

Jianmin Chang
Beijing Forestry University
2011.6.5

Centre for Advanced Research in International Agricultural Development

PRIFYSGOL BANGOR UNIVERSITY

1st June 2011

RE: **Short rotation forestry and Agroforestry: an exchange of experience between CDM countries and Europe**, June 20-22nd 2011 (Barolo, Italy)

Dear Organisers and Participants of the final Benwood meeting,

As a Benwood project partner, we are noticing at Bangor, the benefits of scientific exchange about short rotation forestry (SRF). The Benwood project has provided an important means for people from a variety of disciplines and countries to discuss their experience of trade-offs and synergies amongst energy production, food and environment associated with SRF and agroforestry. A major issue at the moment is the balance between food and biofuel production. I am pleased to see that this issue will be covered, with an opportunity for rich discussion of projects around the globe, at the final meeting.

Bangor University's role within Benwood has been to facilitate a developing country perspective, particularly in Africa, through our collaboration with ICRAF. This has included looking at SRF and its viability in an African context and the ethical concerns tied up with whether biofuel plantations compete with or enhance food security and the extent to which smallholders and rural communities benefit. Short rotation forestry is not without its challenges and controversies and an important consideration, particularly in developing countries, is the need for sustainable livelihoods for the rural poor. Plantation systems are not an option for the majority of farmers in Africa and agroforestry practices are encouraged for many of them with the added advantage that they may buffer against extreme climatic, pest and disease events.

We commend all of the Benwood partners for their continued efforts at encouraging and participating in knowledge exchange within the Benwood project and its associated events. We would like to wish you all the best success for this final project meeting.

Yours sincerely,

Dr Fergus L. Sinclair
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Full papers

Casuarina clone based profitable business agroforestry models for Tamil Nadu

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Introduction

Casuarina is one of the most promising tree species for pulp wood production. The area under *Casuarina* in Tamil Nadu is increasing very fast due to the assured market, high returns from trees and credit facilities offered by the financial institutions. Thus the introduction of *Casuarina* hybrid clones under agrisilviculture system might not have only improved the biomass production and the income of farmers and fulfilling their basic needs of supplementary foods but also improve the micro site enrichment due to the integration of pulses, vegetables and other intercrops. Further more, intercropping of annuals along with trees may offer the advantages of reduced tree establishment costs, income generation during the early period of growth, proper resources utilization, employment generation and supply of raw material for industrial and domestic needs. Hence, study was conducted to evolve profitable intercrops for C*asuarina* clone based agroforestry models for TamilNadu.

Material and methods

A field experiment was conducted to evolve suitable intercrops and also to fix the optimum spacing for intercropping in clonal plantation of *Casuarina*. The recommended spacing for *Casuarina* is 1.5 m x 1.5 m. Hence, close spacing was taken for this experiment. The experiment was laid out in split plot design with three replications. The tree spacing *viz*., 2 m x 1 m, 2 m x 1 m paired row, 2 m x 2 m and 1.5 m x 1.5 m were accommodated as main plot treatments and the intercrops *viz*., cowpea, blackgram, groundnut, gingelly, tomato, bhendi and small onion were taken as the subplot treatments. The trial was continued up to 18 months of tree growth during which three successive intercropping was taken. The productivity and economics of C*asuarina* based agroforestry models was worked out by the following economic indicators viz., B-C ratio and land equivalent ratio. The volume of trees was worked out and converted in to tonnage and benefits were arrived at.

The B-C ratio was arrived at by the following formula;

$$\text{B:C ratio} = \frac{\text{Present value of the net cash flow}}{\text{Present value of the investment}}$$

The B-C ratio should be greater than one. Then only the intercropping system is profitable.
Land equivalent ratio (LER) was used to evaluate the productivity and land use efficiency of the mixed cropping system. It was calculated by the following formula;

$$\textbf{LER} = \frac{\text{Tree yield in intercropping system}}{\text{Tree yield in monoculture system}} + \frac{\text{Crop yield in intercropping system}}{\text{Crop yield in monocropping system}}$$

LER **<** 1 **=** Yield disadvantage for intercropping (the system suffers from competition)
LER **=** 1 **=** Intercropping has no advantage over monocropping.
LER **>** 1 **=** Yield advantage for intercropping (intercropping is better than monocropping).

Results and discussion

Benefit-Cost Ratio:

BCR is obtained when the sum total of benefit stream discounted at 12%.. (i.e present worth of benefit stream is divided by the sum total of present worth of cost stream). During first intercropping when the trees were 6 months old, the intercrops viz., cowpea, blackgram, groundnut, bhendi and sesame obtained higher B-C ratio (2.07 to 4.08) except for tomato and small onion which recorded lower B-C ratio (Table 1). During second intercropping when the trees were 12 months old, the intercrops viz., cowpea, groundnut, blackgram and bhendi again recorded the higher B-C ratio of 1.65 to 3.55 (Table 2). During third intercropping when the trees were 18 months old, the intercrops viz., cowpea alone recorded the B-C ratio of more than 2.0 (Table 3).

Table 1. Benefit: Cost ratio of intercropping (*) under *Casuarina* (6 months old)

Tree spacing	Cowpea	Blackgram	Groundnut	Sesame	Tomato	Bhendi	S. Onion
M_1 (2m x 1m)	4.01	3.42	2.74	2.37	0.92	2.79	1.25
M_2 (2m x 1m) paired row	3.86	3.57	2.81	2.67	0.93	2.74	1.41
M_3 (2m x 2m)	4.08	3.80	2.83	2.82	1.02	2.87	1.45
M_4 (1.5m x 1.5 m)	3.17	2.68	2.41	2.07	0.71	2.19	1.00
Sole crop	4.23	3.94	2.95	3.43	2.22	3.08	3.11

* Benefits and costs involved with intercrops only are considered for computation

Table 2. Benefit: Cost ratio of intercropping (*) under *Casuarina* (12 months old)

Tree spacing	Cowpea	Blackgram	Groundnut	Sesame	Tomato	Bhendi	S. Onion
M_1 (2x1m)	3.33	2.02	2.68	1.47	0.71	1.92	0.97
M_2 (2x1m) paired row	3.08	1.95	2.59	1.34	0.69	1.82	0.85
M_3 (2x2m)	3.55	2.29	3.14	1.75	0.90	2.26	1.28
M_4 (1.5x1.5 m)	2.65	1.65	2.49	1.16	0.66	1.74	0.82
Sole crop	4.16	2.76	2.35	3.27	3.51	3.35	3.30

* Benefits and costs involved with intercrops only are considered for computation

Table 3. Benefit: Cost ratio of intercropping (*) under *Casuarina* (18 months old)

Tree spacing	Cowpea	Blackgram	Groundnut	Sesame	Tomato	Bhendi	S. Onion
M_1 (2x1m)	2.16	1.82	1.53	0.48	0.00	0.62	0.74
M_2 (2x1m) paired row	1.97	1.75	1.29	0.37	0.00	0.33	0.54
M_3 (2x2m)	2.95	2.06	1.73	0.56	0.00	0.55	0.78
M_4 (1.5x1.5 m)	1.47	1.49	1.09	0.29	0.00	0.32	0.32
Sole crop	2.95	2.70	2.01	2.65	3.11	0.18	2.43

* Benefits and costs involved with intercrops only are considered for computation

A study conducted at Rajasthan, Gujarat and Uttar Pradesh in India revealed (Mathur *et. al*, 1984) that compared with pure agriculture or pure silviculture, agroforestry land management system gave the highest B/C ratio (2.28). Kondas (1983) also reported a high BCR of cowpea in association with trees (*Faidherbia albida, Albizia lebbeck* and *Acacia ferruginea*); the lowest returns were realized from sole annual crops.

Returns from the tree + intercrop systems were substantially higher in comparison to tree alone. Among the spacing, the widest spacing of 2m x 2m recorded the maximum B:C ratio and the lowest mean was under 1.5m x 1.5m. Returns were higher in *Casuarina* clone based agroforestry by 3-4 times in comparison to cultivation of tree alone in the first year of growth (Tables 4 to 7). Financial indicators such as the net returns and B:C ratio were also higher with tree + intercrop systems in comparison to the tree alone. Though, the intercrop cultivation required additional expenditure which was mainly due to the cost of the planting material, intensive management, irrigation, weeding, however, the additional returns from the intercrops have compensated these costs. Thereby, intercropping in the initial years allows better cash flow during early growth periods when revenue from trees is not forthcoming Moreover, in the present set of investigations the synergetic effect of intercrops on the growth and productivity of *Casuarina* was explicit compared to the tree alone treatments throughout the stand density treatments.

Table 4. Productivity and economics of *Casuarina* clone based agro forestry system at 2m x 1m spacing during 1st year

Treatments	Production of wood (ton ha^{-1})	Production of intercrops (ton ha^{-1})	Total cost of cultivation (Euros ha^{-1})	Return from different component of the system (Euros ha^{-1})			Net returns (Euros ha^{-1})	B:C ratio
		(Two crops)*		Tree	Crop	Total		
Tree + Cowpea	10.13	1.51	556	317	711	1028	472	1.84
Tree + Black gram	11.87	1.15	557	370	539	909	352	1.63
Tree + Groundnut	8.90	1.90	728	270	893	1163	435	1.61
Tree + Gingelly	10.69	0.73	531	334	456	790	259	1.49
Tree + Tomato	8.29	3.59	679	259	337	596	(-)83	0.8
Tree + Bhendi	10.43	10.78	646	326	842	1168	522	1.81

Tree + Small onion	11.36	3.90	795	354	731	1084	289	1.36
Tree alone	6.57	-	448	214	-	214	(-)234	0.47

Table 5. Productivity and economics of *Casuarina* clone based agro forestry system at 2m x 1m paired row spacing during 1st year

Treatments	Production of wood (ton ha^{-1})	Production of intercrops (ton ha^{-1})	Total cost of cultivation (Euros ha^{-1})	Return from different component of the system (Euros ha^{-1})			Net return (Euros ha^{-1})	B:C ratio
		(Two crops)*		Tree	Crop	Total		
Tree + Cowpea	14.28	1.433	45100	28600	43000	71600	26500	1.59
Tree + Black gram	19.22	1.166	45200	38400	35000	73400	28200	1.62
Tree + Groundnut	16.7	1.914	56100	33400	57400	90800	34700	1.62
Tree + Gingelly	8.48	0.737	43500	17000	29500	46500	3000	1.07
Tree + Tomato	17.94	3.065	53000	35900	21600	57500	4500	1.08
Tree + Bhendi	10.55	10.442	50900	21100	52200	73300	22400	1.44
Tree + Small onion	17.36	4.08	60400	31700	49000	80700	20300	1.34
Tree alone	10.36	-	37600	20700	-	20700	-16900	0.55

Table 6. Productivity and economics of *Casuarina* clone based agroforestry system at 2m x 2m spacing during 1st year (Euros)

Treatments	Production of wood (ton ha^{-1})	Production of intercrops (ton ha^{-1})	Total cost of cultivation (Euros ha^{-1})	Return from different component of the system (Euros ha^{-1})			Net return (Euros ha^{-1})	B:C ratio
		(Two crops)*		Tree	Crop	Total		
Tree + Cowpea	7.29	1.57	408	228	739	967	559	2.37
Tree + Black gram	5.75	1.28	409	180	603	783	374	1.91
Tree + Groundnut	5.42	2.20	579	169	1033	1202	623	2.07
Tree + Gingelly	5.38	0.83	382	169	518	687	305	1.80
Tree + Tomato	4.97	4.17	531	155	390	545	14	1.03

Tree + Bhendi	6.11	11.55	498	190	903	1093	595	2.19
Tree + Small onion	6.18	4.75	647	194	890	1084	437	1.68
Tree alone	4.28	-	300	134	-	134	(-) 166	0.45

Table 7. Productivity and economics of *Casuarina* clone based agroforestry system at 1.5m x 1.5m spacing during 1st year

Treatments	Production of wood (ton ha^{-1})	Production of intercrops (ton ha^{-1}) (Two crops)*	Total cost of cultivation (Euros ha^{-1})	Return from different component of the system (Euros ha^{-1})			Net return (Euros ha^{-1})	B:C ratio
				Tree	Crop	Total		
Tree + Cowpea	11.48	1.20	523	359	564	923	400	1.76
Tree + Black gram	9.81	0.90	525	306	420	726	201	1.38
Tree + Groundnut	8.61	1.60	695	268	753	1021	326	1.47
Tree + Gingelly	6.73	0.64	498	210	400	610	112	1.23
Tree + Tomato	9.34	2.97	647	292	278	570	(-)77	0.88
Tree + Bhendi	9.99	8.78	614	312	686	998	384	1.63
Tree + Small onion	8.99	3.19	763	281	598	879	116	1.15
Mean	7.59	-	415	238	-	238	(-) 177	0.57
Tree alone	11.48	1.20	523	359	564	923	400	1.76

Initial investment was high for *Casuarina* clone based agroforestry systems because of high cost of the clonal planting material, its transportation to the field, pitting and planting, etc. Due to this, net returns from all the *casuarina* alone treatments (throughout different stand densities) in the first year were negative. Despite the high investment, the volume accrued (estimated wood production per hectare) in the tree alone treatment was minimal as compared to the *Casuarina* trees grown along with the intercrops. Meanwhile, intercropping in *Casuarina* provided some income from annual crops also in the first year of growth. These twin benefits of intercropping confidently reflected in the total net return from tree + intercrops combinations.

The financial parameters like total net return and BCR of *Casuarina* clone based agroforestry system indicate that agroforestry based on widely spaced rows (2m x 2m) in the present study) of *casuarina* is more profitable than intercropping in 1.5m x 1.5m spacing without sacrificing the stand density of trees and the total wood production per hectare.

Land Equivalent Ratio :

LER is a measure of the degree to which intercropping gives higher returns to land area than monocropping. The data on LER revealed that there was marked difference in LER with respect to the intercrops. Among the tree + intercrop combinations, tree + cowpea, tree + black gram and tree + ground nut were showing the highest LER. Tree + sesame treatment was the lowest in LER. This combination showed even negative values in tree LER both at 2m x1m paired row (0.819) and 1.5m x 1.5m (0.887) spacing (Table

8). Fadl and Sheikh (2010) reported the effect of *Acacia senegal* on the performance and yield of groundnut (*Arachis hypogea*), sesame (*Sesamum indicum*) and roselle (*Hibiscus sabdariffa*) in an agroforestry system. All the treatments gave land equivalent ratio (LER) of more than one indicating the superiority of growing the field crops in intercropping over the sole cropping of tree alone in the first year of growth of *casuarina*.

Table 8. Land equivalent ratio of intercropping with *Casuarina* (up to 12 months)

Tree spacing	Intercrops	Land equivalent ratio		
		Tree	Intercrops*	Total LER
M_1 (2m x 1 m) (5000 trees ha^{-1})	Tree + Cowpea	1.542	0.874	2.416
	Tree + Black gram	1.807	0.812	2.618
	Tree + Groundnut	1.355	0.813	2.168
	Tree + Gingelly	1.627	0.619	2.246
	Tree + Tomato	1.262	0.310	1.572
	Tree + Bhendi	1.588	0.770	2.358
	Tree + Small onion	1.729	0.358	2.087
	Mean			2.209
	Tree alone	1.000	--	1.000
M_2 (2m x 1 m paired row) (7500 trees ha^{-1})	Tree + Cowpea	1.378	0.826	2.205
	Tree + Black gram	1.855	0.823	2.678
	Tree + Groundnut	1.612	0.816	2.427
	Tree + Gingelly	0.819	0.625	1.443
	Tree + Tomato	1.732	0.265	1.996
	Tree + Bhendi	1.018	0.746	1.764
	Tree + Small onion	1.676	0.374	2.050
	Mean			2.081
	Tree alone	1.000	--	1.000
M_3 (2m x 2 m) (2500 trees ha^{-1})	Tree + Cowpea	1.703	0.909	2.613
	Tree + Black gram	1.343	0.907	2.250
	Tree + Groundnut	1.266	0.939	2.205
	Tree + Gingelly	1.257	0.704	1.961
	Tree + Tomato	1.161	0.361	1.522
	Tree + Bhendi	1.428	0.826	2.253
	Tree + Small onion	1.444	0.436	1.880
	Mean			2.098
	Tree alone	1.000	--	1.000
M_4 (1.5m x 1.5m) (4444 trees ha^{-1})	Tree + Cowpea	1.514	0.694	2.208
	Tree + Black gram	1.292	0.632	1.925
	Tree + Groundnut	1.134	0.684	1.818
	Tree + Gingelly	0.887	0.543	1.430
	Tree + Tomato	1.231	0.257	1.487
	Tree + Bhendi	1.316	0.627	1.943
	Tree + Small onion	1.184	0.292	1.477
	Mean			1.755
	Tree alone	1.000	--	1.000

The total LER was greater than one in all the C*asuarina* clone based agroforestry combinations emphasizing that intercultivation is advantageous to the monocropping of *Casuarina* trees and crop alone.

Conclusion

The most suitable intercrop is cowpea followed by groundnut and black gram in *Casuarina* clone based agroforestry system. The optimum spacing for *Casuarina* clone for intercropping without sacrificing the stand density of trees was 2m x 1m paired row spacing and this spacing was superior to the recommended spacing of 1.5 m x 1.5 m in all respects. The intercropping also had a strong complementary effect on the growth and productivity of *Casuarina* clone in comparison to monoculture. The economic parameters revealed that intercropping with *Casuarina* improve the income of farmer and economically viable when compared to monocropping of *Casuarina* plantation.

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Environmental and financial viability of CDM afforestation in dryland Uzbekistan

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Introduction

Since its establishment in 2001, Clean Development Mechanism (CDM) of the Kyoto Protocol remains the first primary international program for carbon offsets. Despite numerous shortcomings in the "learning-by-doing" implementation, CDM has managed to establish a global, $2.7 billion worth market for greenhouse gas emission reductions, involving over 70 developing countries (Gillenwater and Seres, 2011). Afforestation and reforestation, the only land-use activities eligible under CDM, have not been considered a success as evidenced by their 0.6% share of the total number of the CDM projects approved. As main reasons identified were high transaction costs, precluding in particular small-scale projects, the lack of forestry expertise in the project preparation, convoluted methodological and documentation procedures, non-permanence of offsets, as well as issues in CDM governance and in accounting of emissions reductions (Schoene and Netto, 2005; Locatelli and Pedroni, 2006; Thomas et al., 2010).

On the bright side, CDM forestry was recognized to link efforts of reducing emissions and combating land degradation (FAO, 2000). The CDM forestry projects primarily target unproductive and degraded lands, where the criterion of "additionality" is easier to justify (http://cdm.unfccc.int/Panels/ar). Thus the contribution to sustainable development can be enhanced by promoting such projects in agricultural countries, where cropland degradation is a significant threat to livelihoods.

Irrigated drylands that are responsible for over 30% of the total agricultural production, have been underrepresented on CDM agenda due to their presumably low carbon (C) sequestration potential. Global land suitability assessment for CDM *a priori* excluded irrigated areas assuming their high productive value (Zomer et al., 2008), little feasibility of forestry practices due to high irrigation demand of trees, and low cost-effectiveness of dryland projects (Michaelowa A., email communication).

This brief outlines the afforestation of degraded irrigated croplands from the perspective of land reclamation, carbon sequestration potential and cost-effectiveness. Much of the evidence on the remedial value of afforestation has been previously summarized (Khamzina et al., 2011) based on long-term field studies in dryland Uzbekistan, Central Asia. These results laid the ground for estimating the financial viability of retiring degraded irrigated cropland to establish tree plantations (Djanibekov et al., manuscript in preparation).

Afforestation in reclamation of degraded irrigated croplands

Among the principal culprits of low agricultural productivity is the land degradation from salinization that is affecting 30% of all irrigated cropland. In Uzbekistan, almost a half of the arable lands is saline (MAWR 2010) resulting in annual losses of 31 mln USD while withdrawal of highly saline lands out of agricultural production amounts annually to 12 mln USD (World Bank 2002). The adverse effects of land degradation on Uzbekistan's economy are significant given that agriculture accounts for 22% of GDP and employs 33% of labor (Statistical Committee 2010).

Reclamation of saline land via leaching demands large water inputs and a costly maintenance of drainage systems. The growing regional water scarcity could render such technical solutions little feasible for unproductive croplands, requiring alternative strategies. One adaptive option is converting the unproductive fraction of the cropland to high-C stock systems of salt-tolerant tree species. Areas experiencing shallow groundwater tables, commonly found within the degraded irrigated croplands, are viewed as promising for afforestation given the possibility to reduce the irrigation water demand of forestry (Khamzina et al., 2009a).

The study region Khorezm

The land rehabilitation and productive potential of tree plantations was studied in a 2-ha sized experimental afforestation site established on degraded cropland in the lower reaches of the Amu Darya River, in the Khorezm Region of Uzbekistan (Khamzina et al., 2011). The region's entire irrigated area is subject to soil salinity in various extents due to elevated, saline groundwater tables. Khorezm is located within the transition zone of the Karakum and Kyzylkum deserts and is characterized by an arid, extremely continental climate. Mean annual rainfall of 100 mm fall mostly outside the growing season and is exceeded by the potential evapotranspiration of 900–1000 mm. Salt-tolerant trees were expected to develop extensive root systems for effectively tapping into the groundwater given the shallow levels of 1.3–1.8 m and relatively low salinity of about 1.8 dS m^{-1} in Khorezm (Ibrakhimov et al., 2007).

The population of Khorezm numbers 1.7 million people with 70% being rural. Agriculture accounts for 35% of the regional GDP (Statistical Committee 2010). The entire cropland of 270,000 ha is cultivated under furrow or flood irrigation. About 50% and 20% of arable land is allocated to cotton and winter wheat, respectively. Both crops are part of the national development strategy and grown according to the state procurement targets (Djanibekov et al. 2010). Some 15-20% of the cropland area is reported as low productive but is cropped nevertheless to fulfill the area-based production targets (that are set low for the marginal lands). The commitment to cotton and winter wheat would prevent alternative cropping but mechanisms exist to request an exemption of the unproductive cropland from the state directives. Considering the risk of losing lease contracts of farmland that may restrain long-term investment in land use (Djanibekov et al., 2010), a short-rotation forestry is viewed as a suitable option because, with an appropriate choice of species, it is able to deliver benefits in a relatively short run.

Ecosystem services generated from land-use change

A judicious choice of species for afforestation would maximize associated environmental services such as biological drainage of elevated groundwater table, improvement of soil nutrient stocks, biodiversity, and amenities (shadow, shelter for livestock, bee foraging, scenic beauty) contributing to overall ecosystem health. Tradable non-timber commodities such as fuelwood, fodder, fruits, and, under CDM, carbon offsets, could provide the cash flows to cover early investments and increase financial attractiveness of this land-use change.

Promising candidate species for afforestation were assessed using multiple physiological and socio-economic criteria that singled out the currently underutilized *Elaeagnus angustifolia* L., *Ulmus pumila* L. and *Populus euphratica* Oliv. (Khamzina et al. 2006). The establishment and growth of these tree species were field-tested under deficit irrigation during 2003-2009, as previously described (Khamzina et al. 2008; 2009b). Irrigated with 80-160 mm yr^{-1}, the plantations successfully established on highly saline soils with the root-zone electrical conductivity (EC) over 20 dS m^{-1}, underlain by shallow (0.9–2.0 m) groundwater with an EC ranging between 1-5 dS m^{-1} (Khamzina et al., 2008).Following the cessation of irrigation after two years, the trees relied on the groundwater alone and produced 10-60 t ha^{-1} yr^{-1} of above-ground biomass (stand density was 5,714 trees ha^{-1}). Thus, by drawing on relatively untapped groundwater resources, afforestation can contribute to water saving as "unused" irrigation water from afforested plots could become available for use on productive croplands.

The ability of some tree species for biological nitrogen (N) fixation can make tree-based systems on degraded land self-sufficient in N nutrition thus requiring no N-fertilization. The amount of N_2-fixed by *E. angustifolia* initially averaged 0.02 t ha^{-1} yr^{-1}, peaked at 0.5 t ha^{-1} yr^{-1} during the next two years, and thereafter stabilized at 0.3 t ha^{-1} yr^{-1} (Khamzina et al. 2009b). According to the classification of Dommergues (1995), species with a N_2-fixing potential of 0.1̃0.3 t ha^{-1} $year^{-1}$ are regarded as highly efficient and *E. angustifolia* would thus fit this category. Consequently, the establishment of tree plantations on the degraded cropland increased soil total N stocks in the upper 20 cm layer by 6-30% in five years. The increase in plant-available soil N was the highest under *E. angustifolia* stands. Increases in the concentrations of plant-available phosphorus of up to 74% were significant irrespective of tree species, suggesting an efficient nutrient pump (Khamzina et al. 2009b). This improvement in soil fertility is evidence that afforestation with mixed-species plantations can be a sustainable land-use option for degraded irrigated drylands.

The carbon sequestration rate in woody biomass, above- and below-ground, ranged between 3 and 27 t ha^{-1} yr^{-1}, depending on species and tree age. Seven years following afforestation, the bio-carbon stock of the mixed-species tree stand averaged 74±13 t ha^{-1}. Furthermore, the soil organic C stocks rose by 10-35%, adding 2-7 t C ha^{-1} to the upper 0-20 cm soil layer and thus increasing soil fertility. The N_2-fixing *E. angustifolia* was the most effective tree species in soil C sequestration. If such C sequestration in tree biomass occurs in an afforestation project certified under the CDM, the resulting C payments could encourage afforestation in degraded cropland areas.

Financial viability of CDM afforestation

Financial analyses considered the seven-year rotation period for the tree plantations. The Net Present Value (NPV) of afforestation included tCERs over the crediting period of same duration and non-timber products i.e. leaves (as fodder), fruits and fuelwood. The opportunity costs of the land-use change from annual cropping to plantation forestry were estimated through the gross-margins of the strategic crops cotton and winter wheat cultivated in low-productive areas in Khorezm.

Depending on tree species, the NPV of afforestation ranged between 415 and 3,934 EUR ha^{-1} even under the high discount rate of 14% (the latter is as of July 2009, according to the Central Bank of Uzbekistan,). The cultivation of cotton and winter wheat on the marginal cropland resulted in annual losses of 231 and 52 EUR ha^{-1}, respectively (Table 1), despite that the optimal irrigation supply was assumed available for these crops to maximize their yields. Besides the low crop yields on marginal land, the estimated financial losses were mainly caused by the low procurement prices.

Table 1. Net Present Value (NPV) of annual cropping and afforestation after seven years, with and without temporary Certified Emission Reductions (tCERs) and assuming optimal irrigation supply for crops

Type of crop/ Tree species	NPV, EUR ha^{-1}	NPV including tCERs, EUR ha^{-1}	Irrigation amount, mm yr^{-1}
cotton	-231	-231	600
winter wheat	-52	-52	540
E. angustifolia	3,934	4,132	80-160*
P. euphratica	1,185	1,456	80-160
U. pumila	415	512	80-160

*Tree plantations were irrigated only during first two years

The cost structure of CDM afforestation showed that the highest costs occurred at the onset of the project (Figure 1). These consisted of transaction costs associated with a small-scale CDM project in the amount of 206-361 EUR ha^{-1} and of plantation establishment costs comprising 436-543 EUR ha^{-1}.

The largest share of the revenues was provided by fruits (3,612 EUR ha^{-1}) harvested annually in *E. angustifolia* stands. The fruit production tended to decline over time given the high stand density (5,714 trees ha^{-1}) which is not favorable if fruit production is to be prioritized. Fuelwood provided an important contribution to the total revenues generating up to 2,369 EUR ha^{-1} in *P. euphratica* stands. Such new fuelwood source could help reduce the illegal cutting of natural tugay and desert forests and provide a supplementary energy option in rural areas where over 50% of the rural population has insecure or reduced access to gas supplies (http://www.ieguzexpo.com/page/exhibition/clean_energy/71/res) (UNFCC 2001). Potential profits from foliage as fodder were relatively low.

At the average global price of 3.26 EUR per tCER, C payments measured 5-19% of the total revenues from afforestation and ranged from 97 to 271 EUR ha^{-1} depending on tree species. This amount alone would be insufficient to cover the initial investments.

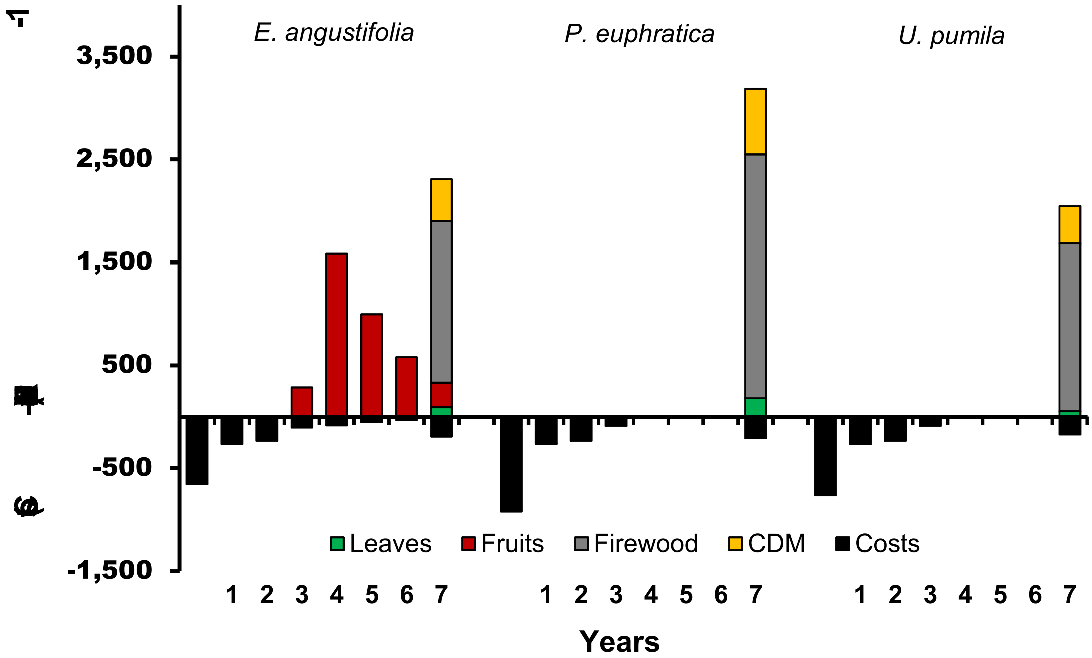

Fig. 1: Cost and benefits of afforestation over a seven-year rotation period

Given the low irrigation requirement of trees (13-30% of the crop water demand), irrigation water saving as a result of afforesting degraded cropland would amount to 35,000-40,000 m^3 ha^{-1} over seven years. This conservative estimate can be more than doubled by including the annual cropland demand for leaching. Expressed in monetary terms using a water price of 0.015 EUR m^{-3} (Djanibekov 2008), the irrigation water saving would amount to 519-606 EUR ha^{-1}. Therefore, accounting for the availability of irrigation water in determining the tCER price would increase the value of dryland afforestation under the CDM scheme.

Conclusions

Overall evidence on ecosystem rehabilitation and financial viability of afforestation under low irrigation supply suggests that setting aside degraded cropland parcels for plantation forestry is an attractive option for irrigated drylands, where shallow groundwater tables prevail. The legislative aspects of retiring degraded croplands and related land tenure issues would need to be amended for exploring Uzbekistan´s small-scale forestry participation in the international carbon market under CDM that links the local and global interests via participatory afforestation. At the current tCER price, little revenues can be expected from carbon sequestration alone, thus C payments need to be considered in the framework of other benefits, such as provisioning of non-timber products. Nevertheless, in the absence of other incentives for land rehabilitation via tree plantings, the carbon sequestration reward remains the major motivation to initiate investments in afforestation of degraded irrigated croplands in Uzbekistan.

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Turning to arid areas for timber through short rotation forests: the case of *Melia volkensii*

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Introduction

Kenya's population in 2009 was estimated at approximately 39 million with a gross domestic growth rate of 4.1%. This population depend largely on a forest cover estimated at less than 3% and is continuously decreasing because of forest degradation and excisions. The population will have a significant impact on the forestry sector as it demands various forest products; put more pressure on land and forest resources; and the global need to conserve biodiversity and protect watershed increases. The arid and semi arid lands (ASALs) cover over 80 % of the country's total surface area (Muturi and Kigwa 2009). These drylands offer the only potential site where forestry activities could expand into due to the high priority afforded agriculture and settlement in the less than 20 % humid area. Tree species adapted to these dry environmental conditions are therefore being promoted and developed into forest plantations for provision of forest products and services and to reduce the pressure to exploit the natural forests.

Melia volkensii (Gurke) is an important indigenous multipurpose dryland adapted tree species commonly used and valued by farmers in Kenya. In several surveys carried out in different places where the tree grows naturally, farmers have rated the tree quite highly (Roothaert and Franzel 2001; Mulatya 2000). The tree is fast growing and could be harvested for poles, firewood and fodder at 5 years under good management while at 10 years; its logs could be processed into high quality timber for furniture and construction (Mulatya 2002, Wekesa *et al*. 2009). Previous problems of wide scale planting of the species have been due to seed dormancy associated with the hard nut and water impervious seed cover. Over years, however, concerted research efforts by Kenya Forestry Research Institute (KEFRI) since mid 1980s have realised high germination rates (Kyalo 2006). The current challenge to full utilisation of the species remains enhancing survival after planting and hastening initial growth on farms (Kigwa 2003).

Tree seedling establishment in Kenya has in the past been through some form of agroforestry practice where young tree seedlings are intercropped with agricultural crops, more so in the humid areas. The spaces between rows of trees are effectively used to raise agricultural crops up to a period of three years without any significant reduction in yields (Shanmughavel *et al*. 2003; Witcomb and Dorward 2009). In the drylands, however, *Melia volkensii* intercropped with maize was found to suppress crop yields by more than 50% (Mulatya *et al*. 2002; Mulatya 2005). Preliminary findings therefore indicated that where land was not a major constraint, *Melia* trees should be grown in woodlots as monocultures especially in areas receiving low precipitation.

Environmental situation in drylands

The climatic conditions in drylands put very high demands on soil water management. Erratic and low rainfall increases the risk of young tree mortality due to droughts and long dry spells. A lot of soil moisture is lost to the atmosphere through soil surface evaporation. The challenging and adverse conditions demand the use of the limited water resources as efficiently as possible. By increasing soil water content and its subsequent retention, young seedlings survival could be improved significantly.

Several techniques could be employed to increase soil moisture but majority are outright too expensive or just out of reach of the subsistent farmers.

Land preparation to enhance soil moisture

Land preparation is an integral part of plantation establishment with the purpose of securing both high seedling survival and rapid early growth (Kigwa 2003). In agricultural fields, the use of conservation tillage has been shown to improve crop yields significantly compared to traditional methods. This involves the use of cover crops between rows of trees and subsoiler to dig trenches to plant agricultural crops. The trenches capture the runoff and store it for use by the crops. In tree establishment, use of cover crops however, has some limitations. The crops grow faster than the tree seedlings during the first year and eventually cover the trees subsequently suppressing them. The alternative method of establishing trees is through maintaining the ground clean without weeds.

To capture maximum water during rain incidences, the ground surface is ploughed or cultivated before the rains to make the soil porous. Water penetrates easily into such soil without developing into a runoff. At the end of the rain season, the soil surface is again disturbed to create a porous layer on top. Weeds that developed during the rains are removed in this process. This layer of disturbed soil looses moisture through evaporation but more importantly, breaks the capillarity action of siphoning water from below and thus conserves the soil moisture. The soil moisture so retained sustains tree growth for a longer period in the drylands than under ordinary conditions.

Tree planting

Tree planting activities start several weeks before the rains. In woodlots this may involve the staking of planting spots to ensure each individual tree seedling is allocated adequate space to grow. The planting pits, which are larger than in humid areas, are dug and the top soil returned leaving out the subsoil. This enhances the soil nutrients availability in the root zone of the seedling while the loose soil allows easy penetration of rain water. Planting is done as early as possible in dry areas to afford the seedlings maximum opportunity during the rain period. Studies comparing growth of trees planted in pits of different sizes revealed that pits of 100 × 100 ×100 cm were better than those of 45× 45×45 cm (Muturi and Kigwa 2009). During the first year of growth, plants established in large pits registered a significantly higher growth rate. This is an important factor in that most destruction of tree seedlings by small animals takes place when they are tender and therefore palatable. The fast growth also allows the seedling to “escape” from the animals as the growing tip becomes inaccessible to them.

Water harvesting techniques

This literally means trapping surface water and concentrating it around the growing plant. It is usually done to facilitate the growth of the young desired trees or during preparation for planting. The commonly used methods for water harvesting are the microcatchments, contour ridges with furrows and circular bunds. In the dry areas of Kenya, the microcatchments are the most widely used in tree planting. They take different shapes depending on the ground slope and prevailing rainfall. The size of each catchment (which is dependent on the soil type and rainfall) is delineated on the ground and its subsoil transferred to the bund lines which are compacted. The top soil is scrapped off the catchment (to enhance runoff) and accumulated at the planting point to improve soil nutrient for the seedling. The water collection pit is dug at the lowest point of the catchment.

The success of these microcatchments depends on the climate, soil type and the slope of the site. The expected amount of rainfall is used to calculate the size of the catchment from which surface runoff is to be collected. Other important factors include rainfall reliability and distribution. Where the rain occurs mainly as drizzle, infiltration into the soil is increased and surface runoff drastically reduced. However, torrential storms result in the greatest proportion of runoff and hence a large accumulation of water at the planting points. Generally, microcatchments are unsuitable on sandy soils because of the high infiltration rates that prevent runoff.

The infiltration rates, water holding capacities and soil erodibility are also other important soil factors that should be considered in water harvesting. The most suitable soils to promote runoff are those that form a poor permeable surface crust. The deeper soil layers should, however, be free draining to allow ample percolation. Runoff build-up is also affected by the existing vegetation and topography. A slope of 3 to 5 % is suitable for microcatchments construction. In such terrain, risk of soil erosion is minimal and any occurrence is easily contained by the catchment bunds.

Planting of tree seedlings take place once the pit is observed to hold water for at least three days without drying up. For species that are sensitive to water logging conditions such as *Melia volkensii* and *Azadirachta indica*, they should never be planted in the pit. Rather these should be planted outside the pit at the base of the catchment bund on the lower side.

Other water conserving techniques

Several other techniques are utilised to conserve soil moisture in the dry areas. They include: mulching with vegetative plant residue; sand; small rocks and pebbles; old tyres; and bottles.

Mulching

Mulching involves covering the ground with vegetative material thereby reducing the ground temperature. This in turn minimises the evaporation rate from soil. Over time, the vegetative mulch biodegrades, thus releasing nutrients to the plant and improves the soil structure by enhancing the organic matter. However, where termites are a menace to the planted trees, vegetative mulch should never be used as they attract the pests. In such situations, alternative techniques of conserving soil moisture should be employed.

Sand mulch

Sand is placed around the base of the seedling and further loosened to aerate it. The loose sand curtails the capillarity action of siphoning soil moisture from the ground and through evaporation into the atmosphere.

Small rocks and pebbles

When placed around the base of the seedling, they directly curtail the direct heating of the soil and thus reduce the evaporation rate. Further, they create an environment in which air movement is drastically reduced. Subsequently the conversion of ground water into vapour is significantly reduced.

Old tyres

For the establishment of ornamental trees around homesteads, old tyres are used for conservation of soil moisture (Figure 1). The seedlings are planted in the middle of a tyre flat on the ground. Water is poured into the tyre and introduced to the plant seedling through a hole on the lower side or siphoning with a narrow pipe. The tyre may also be slightly buried into the ground and thus trap and retain rain water for use by the plant for an extended period of time.

Fig. 1: Seedling planted using old tyre to conserve soil moisture

Weed control

Tending of planted trees (growing space, size of planting pit, weeding) play an important role in the tree growth especially in the arid and semi arid areas by influencing the degree for competition for nutrients, moisture and light between trees and between trees and weeds. Weeding may be done in spots of various sizes, in strips or over the entire planted area depending on factors such as soil structure, terrain, labour availability, the budget and size of the seedlings. Among more established trees slashing of weeds and climbers may be adequate

Spot weeding

This is the maintenance of weed free patches around individual seedlings. It is normally carried out manually and is the most preferred method because it is cheap and requires minimum investment. The size of the spot cleared off weeds against the size of the seedling determines the tree growth performance. Usually, the bigger the seedling, the larger the spot should be to provide the desired effect. Normally a spot of one metre diameter should be considered the absolute minimum in the drylands.

Strip weeding

It involves maintaining weed free strips of land along the tree planting lines. It is usually done manually but could also be done using draught animals. Strip weeding is an improvement over spot weeding but is more expensive. The weeded strips are aligned along the contour to avoid soil erosion. The areas next to the seedling are weeded manually wherever draught animals are used to ensure the seedlings are not damaged. Strips that are not weeded provide soil erosion control areas even when storms are experienced.

Complete weeding

Complete weeding of tree seedlings is similar to the maintenance of agricultural crops on farms. It is the most preferred method in the drylands where farmers practice agroforestry system. Though expensive to implement, it improves the tree growth and allows the provision of protection against animals in the early years of establishment. The expenses incurred are, however, compensated by the harvest realised from the agricultural crops. On steep areas, complete weeding could unfortunately lead to severe problems of soil erosion if control measures are not put in place.

Damage to tree crops

Browsing by small wildlife especially dik diks is common in the dry areas. However, where extended plots are planted, the tree population overwhelms the animals thus reducing the overall effect. Additionally maintaining a clear planted area discourages the animals as they are exposed to the birds of prey. The most critical problem remains the free range grazing lifestyle of the communities in these areas where large herds of animals are kept.

Melia conservation

The species has been subjected to uncontrolled exploitation in its natural range resulting in dominance of poor form trees and very few scattered individuals of good from (Figure 2). To ensure conservation of those identified trees, their scions were collected and grafted on to *Melia* rootstocks in nurseries (Figure 3) and saplings in the field (Figure 4) (Kariuki *et al*. 2008). Over 90 % of the grafts in the nursery were successful. To propagate the superior germplasm, the grafts have been established in hedgerows to provide cuttings on a regular basis (Figure 5). So far the success rate of rooting of cuttings has been low with trials on manipulation of rooting hormones in progressive (Figure 6). Additionally, the use of tissue culture has been curtailed by the heavy infection of vegetative material by fungi, though efforts to control the same continue in our laboratories.

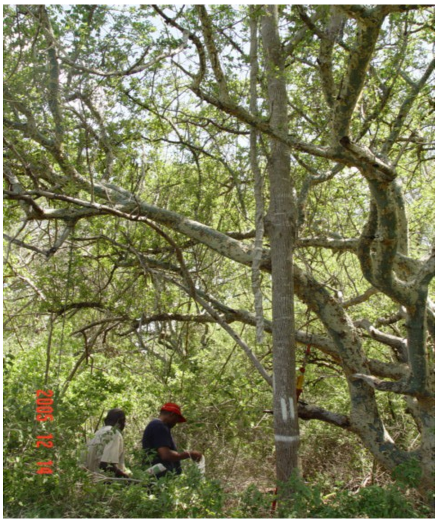

Fig. 2: Selected superior *Melia tree in Mutha Kenya*

Fig.3: Grafted *Melia* seedlings ready for planting in the field

Fig.4: *Melia* scion grafted onto a sapling in Kitui

Fig. 5: Hedgerows of *Melia* grafts in Kenya

Fig. 6: Rooted Melia cutting

Melia growth performance

Growth performance of *Melia* has been monitored over a number of years in several areas with mean annual rainfall of approximately 650 mm (Kamondo *et al*. 2005). At two years the trees had average heights of over 4 m and diameter at breast height of 60mm. By age 10 years, the trees had a attain heights of over 10 m and diameters of 30 cm. However, due to the heavy crown of the species, the bole height was approximately 3 m or less among many trees. Early removal of buds has, however, shown that it is possible to enhance the size of the clear bole with insignificant loss of growth.

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Short rotation forestry - production of biomass by planting Eucalyptus plantations on saline and sodic soils for bioenergy

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Introduction

Most of earth's water contains about 3% NaCl thus making it a salty planet. About 900 M ha land in world is affected due to salts which considerably poses a serious threat to agricultural productivity (Flowers and Yeo, 1995; Munns, 2002) because most agricultural crops will not grow under conditions of high salt concentration. Zhu (2001) reported that worldwide 100 million hectares of arable land is adversely affected by high salt concentration, which reduces crop growth and yield. In India, the area with potential saline soil is about 20 million ha, and about 7 million ha are severely affected by salinity (Mohan et al., 2000). Accumulation of water-soluble salts, especially sodium-chloride (NaCl), sodium carbonate (Na_2CO_3) and partially calcium chloride ($CaCl_2$) results in saline soils.

Wyn (1981) was of the view that soil salinity develops due to high amount of chloride or sulfate salts of sodium. Salt-affected soils have excess of soluble salts and/or excess of exchangeable sodium with accompanying high pH. Both these conditions degrade the soils and render them inhospitable for normal crop/biomass production (in absence of special soil and crop management measures). Soils having soluble salts in excessive amounts are unable to supply water to plants due to osmotic stresses. As a consequence, plants are unable to grow normally in salt-affected soils. The salt content may be an inherent characteristic of the soil or the result of salts being brought up from the deeper soil layers through capillary rise. An other major cause of salinity problem is human activities, i.e. deforestation, waste releasing, irrigation with poor quality water, enriched fertilizer etc. (Pannell and Ewing, 2006).

Salt tolerance is usually assessed as the percent biomass production in saline versus control conditions over a prolonged period of time. Dramatic differences are found between plant species. For example, after some time in 200 mm NaCl a salt-tolerant species such as sugar beet might have a reduction of only 20% in dry weight, a moderately tolerant species such as cotton might have a 60% reduction, and a sensitive species such as soybean might die (Greenway and Munns, 1980). A halophyte such as *Suaeda maritime* might be growing at its optimum rate (Flowers et al., 1977, 1986).

Salt tolerance can also be assessed in terms of survival, which is quite appropriate for perennial species, but for annual species, particularly for broad area or horticultural crops, the rate of biomass production is more useful, as this usually correlates with yield.

Afforestation of these salt affected lands requires careful selection of tree species that tolerate salts (Kuiper and Oldenburger, 2005). Reforestation is one of the most practical and effective strategies to solve the saline soil problems as phytoremediation. Trees cause remediation of saline soil in terms of lowering saline water table, using underground water and decreasing evaporation rate (Barrett-Lennard, 2002). There is evidence that high concentrations of salts have detrimental effects on retardation of germination and growth of seedlings at high salinity and differ in their sensitivity or tolerance to salts (Minhas et al., 1997). The worldwide occurrence of salinized land has led to the development of methods to increase productivity of agricultural wastelands (Dudal and Purnell, 1986). However, the lack of salt-tolerant fast grown clones of Eucalyptus is an important barrier to solve this problem as well as producing biomass for electricity generation and for paper and pulp etc. The salt tolerance of particular clone/species is a crucial factor in its success in providing environmental and economic benefits when grown under saline conditions (Dale and Dieters, 2007). Using vegetation for salinity control is a challenge and it can be overcome by the development of plantations technology for planting these soil with sufficiently tolerant species/clone that provide commercial products as well as environmental benefits (Bartle et al., 2007).

Clones of eucalyptus being grown in different countries

In India, Kulkarni (2001) from ITC Bhadrachalam has screened Eucalyptus clones and selected best clones for clear bole (19) high productivity (15) adaptability to refractory sites (19) disease resistance (6) alkalinity (27) and for site specific clones (11) for paper and pulp production. The original 20 g x c (hybrid clones of *E. globulus* × *E. camaludulensis*) clones were screened in Australia and two clones, clone 11 and clone 20 out preformed under Australia conditions. Further, clone M 80 and M 66 were studied for salt/water tolerance in Australia by Bell 1999 and he reported that clone M80 possess greater ability to exclude Na^+ and Cl^- than clone M 66. However, clone M 66 has greater ability to take up saline ground water than M 80. Sachs et al., (1999) reported the clones developed from *Eucalyptus camaldulensis* (G T-1 and GT-2), *Eucalyptus trabutii* (TT-1), *E. caldocalysis* (CC-1, CC-2) and *E. tereticornis* (TC-1, TC-2, TC-3,TC-4, TC-5, TC-6,TC-7 and TC-8 were tested in USA. Original Eucalyptus clones (developed from *E. camaldudensis* Delm and *E. rudis* Endl) were studied in USA and their performance for biomass production on average and high salinity levels of soil. On soils with average salinity was reported in terms of root growth rate and biomass production , clone no. 4501, 4573, 4590 recorded high root growth rate whereas clone No.4544 and 4543 have recorded low root growth rate. On soils with high salinity, clone no 4501, 4544 and 4573 recorded high root growth rates whereas in clone 4590 and 4543 lower root growth rate was observed in same soils. As for biomass production was concerned clone 4501 and 3490 performed exceptionally best). Few hybrid clones of *E globulus x tropical sp.(Eucalyptus)* are main grown in Portugal and Spain. In Uganda, hybrid clones of *E. grandis x E camaldulensis* (GC) and *E grandis x E urophylla* (GU) imported from Africa were tested and these clones have tremendous potential to expand the plant able area for Eucalyptus in Uganda GC clones are suited to drier sites and Gus are suited to hot tropical sites (Anonymous 2008). Wu et al. (2011) reported that best Six clones, namely DH32-28, DH33-27, GL9, DH32-13, DH33-9 and DH32-29, were selected from 23 clones by using simple index selection. Further he suggested clones for growing in southern China; DH32-26 F2, W5, DH32-29, M1, DH32-28, SH1, DH33-9, GL9, DH32-25, DH42-6, THD3, DH196, DH30-10, GL4. In Brazil, clones *E. grandis x E. urophylla*, natural and spontaneous hybrids of *E. uropyhlla × E. grandis, E. urophylla,× E.salinga, E camaldulensis x E. urophylla, E. urophylla x E. globules and E. camaldulensis x E. grandis* clones were grown in 2004 and significant gain in volume 30-40 m^3/ha/yr was achieved. Blake et al. (1988) reported that larger root systems and the ability to limit water loss and plant moisture stress appeared to be correlated with total dry matter production. Species and clones which maintained lower plant moisture stress while under drought grew faster after planting. These plants were characterized by higher xylem pressure potentials under drought and lower leaf area/root dry weight ratios both before and after planting. Oballa et al 2005 reported the species, Land races and clones for various agro climatic zones of Kenya and are presented in Table. 1.

Table 1. Recommended clone of Eucalyptus for different sites in Kenya

Sites	Recommended species or clones
Sokoke	GC 514, GC 785
Msambweni	EC, ET and EU (Local land races) and clones GC14, GC167, GC514, GC540, GC581, GC584, GC784, GC785, GU21, GU47 and GU48
Gede	EC, ET and EU (Local land races) and clones GC14, GC167, GC514, GC540, GC581, GC584, GC784, GC785, GU21, GU7 and GU8
Machakos	EG, ES, GC 14, GC 15, GC 10, GC 522, GC 581, GC 642
Karura	GC 15, GC 10, GC 522, GC 581

Embu	GC 15, GC 14, GC 581, GC 642
Hombe	EG, GC 522, GC 581
Timboroa	ES, GC 3, GC 14, GC 15, GC 581 and GC 642.
Marigat	GC 514, GC 540 and GC 784

Morabito et al. (1996) reported the differences in response for uptake of Na^+ and Proline content in two clones of *Eucalyptus microtheca.* Chaum and Kirdmanee(2008) have developed salinity index on the basis of net photosynthetic rate of the plantlet raised *in vitro* to screen in a fast way clones against salinity.

Effects of soil salinity on growth and uptake of ions of eucalyptus clones

Morabito et al. (1996) reported that clone 42 demonstrated a delayed growth during salt stress while clone 43 showed a complete inhibition of shoot length. Salinity had a significant effect on mineral compounds: whatever the duration of the salt treatment, the uptake of sodium in roots was 2.5 times higher in the more tolerant clone 42 than in clone 43. Regarding potassium and calcium contents in roots, clone 42 demonstrated an increase in its amount whereas clone 43 showed a decrease. The increase in soluble amino acids induced by the stress in the different organs of the two clones was not significantly different whereas a higher content of proline was determined in clone 42 relative to clone 43. Salinity had significant effects on the content of one of the predominant polypeptides with an apparent molecular height of 18 kDa which was specifically induced under salt stress in roots of clone 43. In clone 42, this polypeptide was present in low amounts in control conditions and salt treatment increased its synthesis.

Use of physiological attributes and devices for ranking of clones for salt tolerance

Jenneth et al. (2003) reported that chlorophyll attribute (light adapted attribute F_{ds}, when measured in a controlled environment, did decline, often before physical symptoms of stress were visible. This value is required for the derivation of effective quantum yield, and each measurement can be acquired and automatically recorded in a few seconds, permitting the rapid survey of large groups in a propagation facility. Monitoring of plants that were treated with increasing concentrations of NaCl over time, permitted overall ranking of the responses of groups of clones of *Eucalyptus camaldulensis* and *E. urophylla* × *E. grandis.* The EM38 (electromagnetic induction meter) was found to be an effective tool in determining survival and growth responses of three Eucalyptus species to levels of soil salinity (McKenzie et al., 1997). Differences in measured tree survival stand volume and leaf area index were correlated with soil salinity (Feikema and Baker, 2011). Salt tolerant or halophytic species seem to lack the unique metabolic machinery, which is sensitive to or activated by high toxic-ions, especially Na^+ and Cl^-. Defense responses of halophytic species comprise of many mechanisms such as osmoregulation, ion homeostasis, antioxidant and hormonal systems (Hasegawa *et al*., 2000; Ashraf and Foolad, 2007). Therefore, there are many reports that depict that salt-tolerant species can be categorized using physiological criteria such as chlorophyll content and chlorophyll fluorescence (Percival and Fraser, 2001). In that case, net-photosynthetic rate (NPR) is one of the candidate physiological parameters, which is simple, rapid, and sensitive method to establish the salt-tolerance index (Ashraf, 2004). Van der moezel et al. (1988) reported that under non-saline conditions, waterlogging induced stomatal closure in *E. camaldulensis* and *E. lesouefii* . However, the stomata of *E. camaldulensis* reopened after five weeks, when adventitious roots were produced. Relative to that of controls, height growth of waterlogged seedlings was greater in *E. camaldulensis* than in *E. lesouefii*, as were rates of photosynthesis and transpiration. In a freely drained medium, high salinity reduced rates of seedling height growth and photosynthesis, relative to those in controls, less in *E. lesouefii* than in *E. camaldulensis*. In both species, height growth, stomatal conductance and photosynthetic rate were lowest under conditions of saline waterlogging.

Javaid et al. (2008) reported that survival and growth of *E. camaldulensis* can be improved under saline conditions through the appropriate choice of planting density. Initial tree spacing has an obvious effect on successive tree growth. The 3.0 m × 3.0 m spacing produced the best results in terms of tree height and wood volume; however, plant diameter was greatest with the 3.5 × 3.5 m spacing treatment at all three sites. The establishment of E. camaldulensis also resulted in a decrease in soil salinity (ECe) after 5 years at all three sites. The maximum reduction in soil ECe was observed at the 3.0 m × 3.0 m plant spacing.

Plantation establishment techniques for salt tolerant tree species (salinity management)

The method showing the best results to establish tree plantations on salt affected soils is the furrow method. This method shows the highest sapling survival in different field studies (Tomar, 1997) and is recommended by the handbook of Quershi and Barret-Lennard (1998). It is an example of how to control soil salinity in the root zones (salinity management). The furrow method works as follows: furrows about 0.6 m wide and 0.2 to 0.3 m deep are created with a tractor mounted furrow maker. The furrows are used for irrigating the saplings for at least two years. The seedlings are planted at a uniform distance. The place where they are planted, depends on the degree of internal drainage of the soil. In soils with good internal drainage the seedlings should be planted at the bottom of the furrow. In soils with poor drainage the saplings are planted on the shoulder of the furrows so that they are not affected by water logging after irrigation. In waterlogged soils the trees should be planted on buds or mounds to avoid water logging. The trench-ridge technique is widely used in Pakistan and India on waterlogged soils. As soils are heavier, more salt-affected and waterlogged mounds should be taller and wider, and have a distinct trough. Such double-ridge mounds have proven very effective by providing (1) site drainage, (2) elevation of the seedling above the water table (thereby increasing oxygen availability) and (3) salt leaching from the root zone. These mounds are particularly useful where there is sufficient rain and/or irrigation water before planting time to leach salts from below the trough at this critical time. It is best to construct mounds several months before planting. Single-ridge and flat-topped mounds are not as effective, but are better than no mounds. Several techniques are available for mechanically forming mounds. Equipment includes: press wheels attached to the mounds of the plough, modified direct seeding machinery and twin discs (Marcar and Crawford, 1996; Lambert and Turner, 2000). Ghafoor et al. (2001) reported that among residual sodium carbonate treatment amendments, the use of gypsum is economical and safe, while acids could accomplish the same but at a much higher cost. For reclaiming saline soils (ECe ≥4.0 dSm^{-1}, SAR ≥13.0), no amendment require rather simple leaching with all type of water (canal, groundwater, agricultural drainage) is useful during early phase of reclamation following a gradual shift towards sweet water application. For saline-sodic (ECe ≥4.0 dSm^{-1}, SAR ≥13.0), and sodic soils (ECe ≥4.0 dSm^{-1}, SAR ≥13.0), Ca carriers (Gypsum calcium chloride, Calcium nitrate, Phospho gypsum, later three being industrial by products 0 are economical, acids (H_2S04, HCl, HNO3) or acid formers (Sulphur, Calcium poly-Sulphide, Pyrite, Ferrous Sulphate) can reclaim such soils relatively at a faster rate but at 5-10 times higher cost.

Results of the study by (Minhas et al.1997) indicated that irrigation should at least be applied in the first two years after planting. In most cases the trees have developed their rooting system after two years and are able to reach the groundwater. Irrigation should be managed for trees on saline soils in such a way that it avoids water logging and aeration problems, and the accumulation of salt in the root zone. These objectives are met with the furrow irrigation method (Tomar., 1997). With the furrow irrigation method, saline waters of EC up to 15 dSm^{-1} in sandy loam and on loamy sand soils can be used. In fine textured soils, waters of EC up to 8-10 dS m can be used for irrigating saplings. The recommended irrigation interval for brackish water is the same as for normal water. In India they have the following scheme: a monthly irrigation during October-March, and fortnightly irrigation during April-June (Tomar, 1997).

The distance between the saplings in a row and between rows is dependent on the species, but also on whether the trees are to be planted in blocks, mixed with shrub species, or used in alley cropping. In case of the presence of a dense soil layer or hardpan the furrow planting method is combined with the auger hole method. Auger holes (0.2 m in diameter and 1.2 m deep) are dug at the sill of the furrows spaced at the desired intervals. These holes may be refilled with a mixture of original soil, farmyard manure, super-phosphate, zinc sulphate and iron sulphate to give the saplings a good start.

Agroforestry technologies for managing salt affected soils:

Salt tolerant trees can also be used in agro forestry systems with the purpose of managing dry land salinity. Dry land salinity generally results from the build-up of salts in surface soil, usually as a result of a rising water table and subsequent groundwater seepage. Water tables can rise due to the removal of deep rooting native vegetation, for example in Western Australia. Due to the removal of this vegetation large volumes of rainfall are leaking through the upper soil and recharge the groundwater. This results in raising water tables especially in discharge sites bringing dissolved salts to the surface layer of the soil. Trees can be used to lower these elevated water tables. They are relatively deep rooting and can therefore reduce water leakage; they may use water all the year around whenever it is available, and intercept a significant fraction of rainfall before it reaches the soil. In this way, strategic tree planting being part of agro-forestry and farm forestry systems, can contribute to lowering of water tables. Besides this tree's root exudates and roots itself (after decomposition) helps in improving the soil physical properties.10

Strategies for future research

To bring salt-affected soils under cultivation and to enhance productive eucalyptus plantation on such soils following strategies for future research are suggested:

- To broaden the genetic base in each country clones need to be developed from different species of Eucalyptus and which need to be for better productivity.
- Development of techniques for screening of salt tolerant clone of eucalyptus for deployment for plantations and selection of suitable clones for the development of new clones (through hybridization) resistant to a biotic stress.
- Development of integrated management techniques for agroforestry systems for production of wood, food and other services.
- Standardization of planting density, water and nutrient requirement of different clones of eucalyptus grown on saline and waterlogged soils with a view to reduce water logging and reducing soil salinity.
- Screening of eucalyptus clone may be undertaken for water use efficiency to select clones for sites with varied moisture availability.
- Management options for saline soils coupled with waterlogging needs to be worked out. In such soils the most important issue is to biodrain the excess water through highly transpiring *Eucalyptus* clones (planting density needs to be regulated with respect to age to contract water recharge).

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Fertilizer requirements of poplar and willow

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Introduction

Nitrogen (N) is essential for all living organisms and increases the yields of crops; however at the same time N is a major pollutant of the atmosphere, the waters, and soils. Leading scientists warn that already now the anthropogenic N input into the environment has passed the pollution load capacity (Rockström et al. 2009). A fast and rigorous reduction of N emissions is necessary. The atmospheric input of N into the ecosystems is a major cause for reductions in biological diversity. The overload in coastal waters and formation of detrimental zones in the sea are well-known ecological problems caused by high N inputs. Also in terrestrial ecosystems manifold problems are caused by high N-influxes.

Reactive nitrogen

About 50 % of all N on this globe occurs in form of different gaseous N compounds in the atmosphere of which N occupies about 78 %. Of this N more than 99 % is represented by elemental Nitrogen (N2), which has a strong chemical bond and is thus very stable and not accessible to living organisms (Seinfeld et al. 2006). However, N occurs also in the form as reactive N and is able to form compounds with many organic and inorganic molecules and can shift easily from one form to another. In this form it is accessible for living organisms, which require N to synthesize proteins and DNA.

Climate change and nitrous oxide (N2O) as greenhouse gas

Climate change is caused mainly by CO2, which is emitted world-wide at still increasing amounts into the atmosphere. However, also other greenhouse gases contribute to global warming among them the N compound nitrous oxide (N2O), which is as a potent greenhouse gas 298 times more effective than CO2 (IPCC 2007). The deliberate fertilization with synthetic N of soils as well as the diffuse distribution of N compounds onto the soils over the air causes increased production of N2O, in the soils. The more N is available in the soils, the more N2O is emitted into the atmosphere. Since industrialization N2O has increased by 20 % in the atmosphere, which is due to the high persistence of this molecule. It takes about 100 years before it disintegrates in the stratosphere after passing through the lower layers of the atmosphere. N2O can be attributed 6 % CO2 equivalents as cause for climate change in industrialized regions.

Since the middle of the 19th century a tenfold amount of reactive N is being released worldwide with a significant increase since 1960 (Galloway et al. 2003). It can be presumed that yearly about 150 Million tons (as of 2000) reactive N are emitted into the environment due to anthropogenic activity (Rockström et al. 2009). The massive release of N began with the onset of industrialisation 150 years ago with the increasing use of fossil fuels in industry and traffic. A key impulse for release of N was the technical production of N fertilizer around 1910. Man influences the global N cycle massively. Presently about four times as much N2 is converted into reactive N than the planet earth is able to cope with (Rockström et al. 2009).

With rising energy demand and a rising world population the problem will still aggravate. For these reasons plants should be preferred which need not to be fertilized with high amounts of technically produced synthetic fertilizer for the production of high yields. In such production systems the emission of N2O is much reduced and thus do not contribute to global warming. Parr et al. analyzed the emission of N2O in different fertilizer treatments and crops, among them poplar plantations. In these, the N2O emissions were shown to be five times lower than other crops (Fig. 1) because poplar needs not to be fertilized. Poplar plantations in many regions of the world show that it is possible to produce high amounts of biomass with very low amounts of N fertilizer. The explanation for this special character of poplars has been studied recently. The purpose of this paper is to summarize these findings and discuss the associated opportunities and implications.

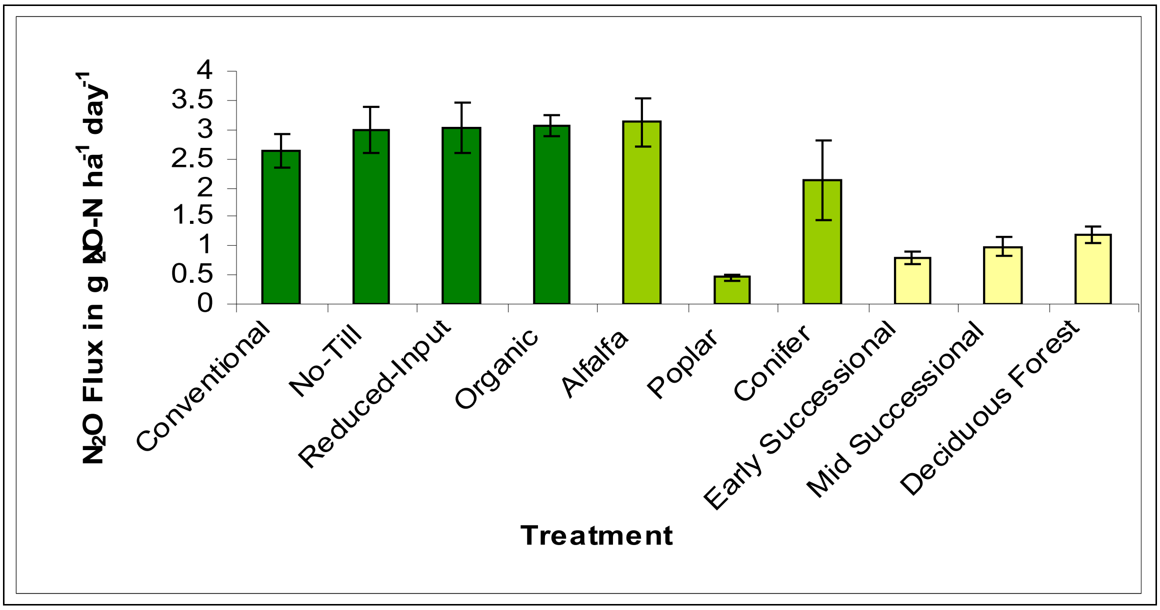

Fig. 1: Nitrous oxide gas (N2O) fluxes across the management gradient over the period 1993 -1997 for conventional and successional management treatments, 1991-2002 for all other treatments. Bars represent mean fluxes (± se, n = 3 or 4 replicable blocks) collected using static flux chambers once in March and twice monthly from April through September, then again once monthly until the ground was frozen. The highest nitrous oxide production was in the annual cropping systems, alfalfa, and coniferous forest, which did not significantly differ from one another. This may be reflective of the high variability that is typical of nitrous oxide production. This suggests that cropping system and disturbance may not be the definitive determinates of nitrous oxide production, but instead availability of N. N2O production was lowest where soil nitrate levels were low. N2O production thus increased with management intensity.
(From Parr et al. http://environment.msu.edu/climatechange/posters/Parr.ppt.)

Poplar and willow

Poplar (*Populus spp.*) and willow (*Salix spp.*) species are early-successional trees with rapid growth and the ability to grow fast, even in nutrient-poor environments. Due to their fast growth, poplar cultivars are grown widely in plantations, mostly in temperate zones. There are about 10 million ha of poplar plantations worldwide. Many trials have examined the factors influencing biomass production of poplar cultivars. These trials show that N fertilization usually has little or no effect (Heilman and Xie 1993; Jug et al. 1999; Liesebach et al. 1999; Coleman et al. 2004; DesRochers et al. 2006; Booth 2008; Mao et al. 2010). Free-air CO2 enrichment experiments (FACE) showed that higher CO2 levels also require higher soil-N. However, poplar was able to increase biomass production under elevated CO2 without additional N (Pregitzer et al. 2000; Luo et al. 2006). Also, no yield response curves and few detailed fertilizer recommendations exist for poplar or willow.

Poplars growing on rocks and gravel in their native riparian habitat were found to have sufficient amounts of N in their tissues despite low soil N availability (Coleman et al. 1994; Lawrence et al. 1997; Cooke et al. 2004). The explanation for the indifference of poplar towards soil N availability has been studied recently and will be discussed in the following summary.

Diazotrophic bacteria

It is well known that a large endophytic community resides in the stem tissue of poplar and willow species, the function of which is still mostly unknown. Ulrich et al. (2008a) found a total of 53 genera including *Proteobacteria, Actinobacteria, Firmicutes, and Bacteroidetes*. In poplar and willow grown in contaminated soil, Taghavi et al. (2009) identified 78 endophytic strains, of which 71% belonged to *Gammaproteobacteria*, with others from *Serratia spp.*, *Rahnella spp., Pseudomonas spp.,* and *Enterobacter spp.* Among these endophytes, several diazotrophic (nitrogen-fixing) bacteria were identified. They remained undiscovered because of their inconspicuous occurrence in the living tissues of the stem and branches and not in root nodules as is found in the legume family (*Fabaceae*).

Legumes form a symbiosis with *Rhizobia*, a genus of soil bacteria capable of biological N2 fixation, where the plant exchanges its carbohydrates from photosynthesis for the combined N from its root nodule inhabitants. In this process, atmospheric N (N2) becomes accessible to the plant by conversion into ammonia (NH3). This conversion requires a high amount of energy in the form of adenosine triphosphate (ATP). Through a particular interaction, a specific bacterium associates with a specific legume, resulting in the familiar root nodules, in which N2 fixation occurs. In addition to the legumes, woody plant species of nine families (*Betulaceae Cannabaceae, Casuarinaceae, Coriariaceae, Datiscaceae, Elaeagnaceae, Myricaceae, Rhamnaceae, and Rosaceae*) are known to associate with other N2 fixing microbes living in specialized root nodules. Well known are *Frankia* bacteria found in *Alnus spp.* of the *Betulaceae* Family.

Verification of N2 fixation in *Salicaceae*

In poplars, endophytic bacteria were found inside stem tissues. These endophytes do not cause disease but rather are beneficial to the host by providing hormones, peptide antibiotics, enzymes, and other beneficial substances; thus, classified as plant-growth promoting bacteria (Doty et al. 2005, 2009; Ulrich et al. 2007; 2008a, Scherling et al. 2009; Doty, 2010). Plant-growth promoting bacteria were found in poplar and willow species (Table 1). Among this array of growth-promoting substances, ammonia is also present in several other plant species without root nodules such as sugar cane, rice, coffee, and sweet potato (Reinhold-Hurek and Hurek, 1998; Xin et al. 2009). Thus, the common conclusion that plant species without root nodules are not associated with N2-fixing bacteria has been proven incorrect.

Table 1: Poplar and Salix species shown to host bacteria for which N2 fixation has been verified by the different methods shown.

Tree Species	Bacterial strain	Method of Verification	Reference
P. trichocarpa × *P. deltoides*	*Rhizobium tropici*	culture on N-free medium	Doty et al. 2005
[*Populus alba* × (*Populus davidiana* + *Populus simonii*) × *Populus tomentosa*]	*Paenibacillus humicus strain P22*	metabolite analysis (urea, CH_4N_2O)	Scherling et al. 2009
P. trichocarpa *Salix sitchensis*	*Burkholderia, Rahnella, Enterobacter, Acinetobacter,*	culture on N-free medium; PCR with *nifH* primer; acetylene reduction assay	Doty et al. 2009
P. trichocarpa	*Burkholderia vietnamensis*	culture on N-free medium; PCR with *nifH* primer; acetylene reduction assay; $^{15}N_2$ incorporation assay; inoculation on other organism	Xin et al. 2009

In order to verify the ability to fix N2, a first screening is efficient by employing the PCR (polymerase chain reaction) to look for the presence of *nifH,* a gene encoding for one of the subunits of nitrogenase, the enzyme facilitating N-fixation (Doty et al. 2009). Conclusive is also the acetylene reduction assay in which positive N_2 fixation activity of bacterial cultures is demonstrated by increased ethylene concentration over time (Doty et al. 2009). Xin et al. (2009) analyzed incorporation of the rare isotope $^{15}N_2$ instead of the common $^{14}N_2$ and showed that a strain of the endophytic bacteria species *Burkholderia vietnamensis* isolated from a wild-grown *Populus trichocarpa* tree was able to fix $^{15}N_2$ by a twentyfold higher concentration of this isotope as compared to normal air. This endophyte was then inoculated onto Kentucky bluegrass (*Poa pratensis L.*) cultured on an N-free medium. After 50 days, the inoculated plants had increased 42 % in weight and 37 % in N as compared to the uninoculated control plants showing that inoculation of N-fixing endophytes may enhance plant growth under N-limiting conditions. This particular *B. vietnamensis* strain is also able to provide IAA, a growth promoting hormone to the hosting plant, which may also have played a role in the biomass gain.

Another example of growth enhancement was shown by Ulrich et al. (2008b) using an endophytic strain P22 of *Paenibacillus humicus* isolated from poplar. It caused a pronounced increase in root number and root length in poplar compared to uninoculated controls. The same effect was found when rooting macro cuttings of this poplar clone (Ulrich et al. 2010). Analysis of the metabolites produced by the inoculated poplar showed that the poplar reacted pronouncedly to the presence of this endophyte by producing much higher amounts of asparagines and plant accessible urea (CH_4N_2O) but reduced amounts of organic acids of the tricarboxylic acid cycle. This effect on the metabolite profiles reflects remarkable changes in N assimilation in the plant (Scherling et al. 2009).

Thus far, it is unknown if diazotrophic bacteria are present in all *Salicaceae* species. It can be expected that fast growing poplar and willow species adapted to riparian habitats with sandy soils poor in N availability are able to fix N_2. With respect to potential uses of plant-growth promoting bacteria, the best approach will be to quantify growth enhancement due to the symbiotic interactions between specific poplar or willow genotypes with specific bacterial strains.

Opportunities for practical use

The technical fixation process of plant-accessible ammonia from molecular N_2 requires an energy-input of 946 kilojoules per mole and is thus highly energy consumptive. For this reason, plants favored for renewable energy crops are those able to produce high amounts of biomass with low requirements for synthetic fertilizer. Furthermore, negative influences of excessive N on the environment (e.g. groundwater leaching, emission of detrimental N_2O, etc.) can be avoided when growing N_2-fixing plants.

The energy source for the biological N_2 fixation is ATP of which an equivalent of 16 moles is hydrolyzed in the process. Biological N_2 fixation is more energy efficient than the inorganic process because it is enzyme supported and because the N is produced in the required amount and location. N_2-fixing plant species have therefore received much attention for reducing fertilizer usage. For these reasons, methods to initiate N_2 fixation in crop species by inoculation of diazotrophic endophytes have been investigated (Cocking 2005).

Because N_2 fixation is an energy intensive process, N_2-fixing plants make ready use of freely available N in the soil. They can therefore be used to sequester surplus N in N-rich sites. For example, poplars and willows are being used to sequester N from sewage sludge (Dimitriou and Aronsson, 2004). Other species, however, may be able to sequester higher amounts of N.

In agroforestry systems, poplar is being grown admixed with numerous crop plants (Yadava 2010). These systems have become common in many places and yield quality crops and high monetary returns for both the poplars and the crop plants (Bangarwa and von Wuehlisch, 2009). In another study, poplars were grown in agroforestry systems with N_2-fixing plants, e.g. *Hippophae rhamnoides* (Mao et al. 2010). Although the soil N increased, there was no biomass increase in the poplars. This unexpected result is easily explainable when considering the N_2-fixing ability of poplar.

Implications for tree improvement

Analyses of endophytic bacteria in poplar and willow individuals showed that the bacterial communities differed considerably between trees (Ulrich et al. 2008a, 2008b; Scherling et al. 2009) indicating that the tree and bacteria interact such that a certain bacterial community evolves within a particular tree genotype. The tree can thus acquire supplementary adaptive characteristics which are not encoded by its genes. This may offset predicted gene expressions, e.g. in marker-assisted selections. The success of artificial inoculations with growth-promoting bacteria depends on the harmony of the bacterial strain and the genotype of the hosting tree.

It would be of practical importance to know the extent to which species or genotypes within the *Salicaceae* family vary in their ability to fix N2. The special spectrum of bacteria found in different host genotypes suggests considerable variability. There may even be species unable to fix N2. This could apply to species having evolved on sites where N was at or above sufficiency. Further research is warranted to better understand differences among genotypes and the potential for tree improvement on sites where N is limiting.

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Insect pests in short rotation coppice in Germany – an overview of their effects, risk potential and control measures

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1. Introduction

A precondition of successful establishment and profitable management of SRC (short rotation coppice) worldwide is the plant's resistance to biotic risk factors. The typical characteristics of SRC, such as low genetic diversity and spatial homogeneity, allow mass developments of insect pests, especially leaf-eating species. These events can lead to yield losses strongly derogating the economy of the plantation.

Thus, the occurrence of insect pest species in various types of SRC in Germany has been monitored for five years. Initially disregarded and underestimated by land users, the influence of and damage by insect pests has become more and more obvious over the years and developed into an essential factor in the management of SRC.

Poplars and willows, preferred tree species for SRC, are inherently associated with a high number of insect species. The intensification of their establishment, plus the fact that SRC provides optimal conditions for insects, increases the risk of mass developments and allows previously harmless species to become pests (Coyle et al., 2005). In addition, the short harvest cycles reduce the plant's time to compensate damage, such as leaf loss or stem damage, and can result in severe yield reductions.

In terms of pest management, SRC has to be regarded as a new ecosystem, since the tree species used are planted in an unnaturally high density on agricultural sites. The colonization of such new habitats by insects can be described using the logistic model of population growth in a new habitat by Schaefer (2003), divided into three main development stages. Very slow initial colonization characterized by low numbers of individuals and species is followed by rapid, exponential population increase which eventually asymptotically approaches a certain limit and stabilizes. The limit is thereby determined by the habitat's capacity and food supply as well as the occurrence of predators, parasites and diseases. Ideally a balance between pests and predators develops. However, it is not clear yet whether this is also achieved in SRC. The results of Björkman (2004) indicate that the short harvest cycles support certain pest species and negatively influence the occurrence of predators.

2. Main insect pests

During the five years of monitoring German SRC, it was found that a certain number of species are widely distributed, whereas others caused severe damage locally, but were never recorded anywhere else. Some of the species are known to occur in forest habitats, but have never been reported to cause actual damage there due to their low population size. The species presented in the following sections were found to cause damage to poplar, willow or black locust SRC in Germany. However, species of the same genera are pests in plantations worldwide.

2.1 Main insect pests on poplar (*Populus* sp.)

In Germany mostly poplar is used for SRC plantations. The observations over recent years revealed *Chrysomela populi* L. (red poplar leaf beetle) to be the main pest in those plantations (Fig.1-4). The species has also reached pest status in other countries of Europe as well as in Asia. Moreover, related species such as *Chrysomela scripta* F. (cottonwood leaf beetle) and *Chrysomela lapponica* L. (palaearctic leaf beetle) are common pest species in poplar and willow plantations in other parts of the world (Nebeker et al., 2006; Zvereva, 2002). In Germany, *C. populi* is spread throughout the country's poplar plantations and occurs in high densities (Helbig and Müller, 2010). Both larvae and imagos feed on leaves. In addition, shoot tips including the buds can be destroyed completely when a large number of individuals occupy a plant. The plantation is particularly sensitive to the beetle when resprouting after being harvested. In a poplar plantation in the south of Brandenburg, the beetle population completely suppressed the development of new shoots by feeding the young buds. When the stools still showed no growth in June, it was decided to combat the beetle with an insecticide. Within a month, the new shoots had developed heights of about one metre (Helbig and Landgraf, 2009).

Fig. 1: Third instar lavae of *Chrysomela populi*

Fig. 2: Supression of resprouting by *Chrysomela populi*

Fig. 3: Mass infestation with *Chrysomela populi*

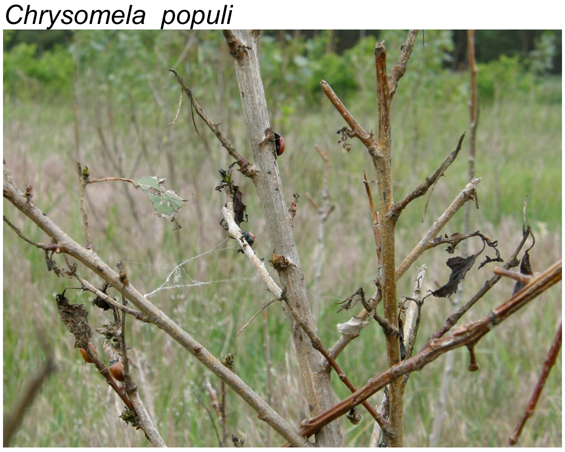

Fig. 4: Severe plant damage by *Chrysomela populi*

During the year, all development stages from different generations infest the sites simultaneously. Laboratory experiments showed the completion of two generations per year for *Chrysomela populi* and an incomplete third for the related but much less common species *C. tremulae*. The imagos hibernate in the soil within the plantation and recolonize the plantations in spring. Upon disturbance, the larvae emit a defence secretion from glands on the sides of their bodies. The secretion is produced from chemical components of the plant. As consequence only few species prey on *C. populi*. Mainly egg predators have been observed. The effectiveness of synthetic and biological insecticides has been tested under laboratory conditions and is presented in section 3.1. The display of preferences for certain poplar varieties (Fig. 5) could help developing plantation designs which reduce the occurrence and the spread of this species. The effect of mixed plantations on species with food preferences are described in section 3.2.

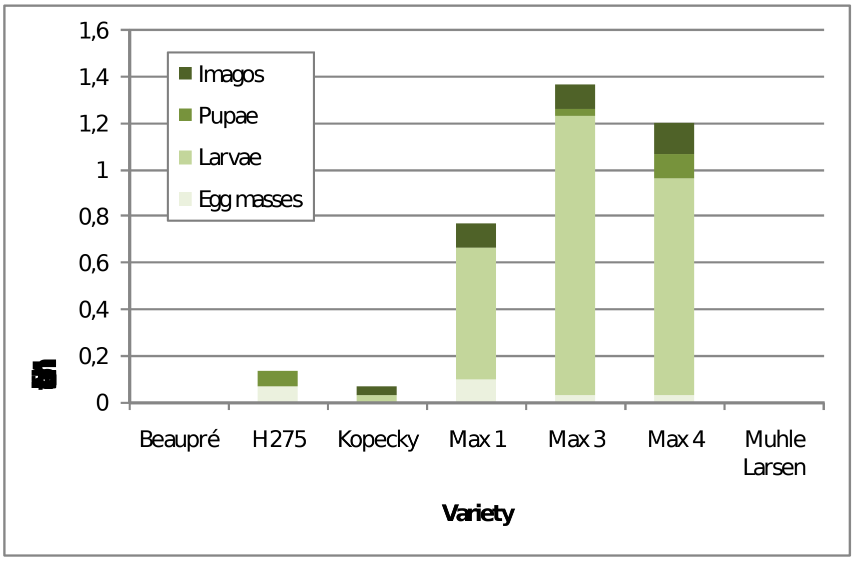

Fig. 5: Occurrence of the development stages of *Chrysomela populi* on different poplar varieties in a SRC plantation in south Brandenburg, Germany

Besides *Chrysomela populi*, *Phratora vitellinae* L. (brassy willow beetle) is a frequent pest species on poplar in Germany. Although its name implies foraging on willow, *P. vitellinae* almost exclusively occurs on poplar (Kendall and Wiltshire, 1998; Sage and Tucker, 1997). A very similar looking species is *Phratora vulgatissima* L., a pest of willow (see section 2.2). The ecology of both *Phratora* species is very similar to *C. populi*. However, they are said to mainly hibernate outside plantations (Björkman and Eklund, 2006), whereas *C. populi* stays within the plantation hidden in the soil. In contrast to the feeding of *C. populi*, larvae and beetles of *P. vitellinae* usually leave a skeleton-like leaf instead of removing it completely. The beetle often occurs in high densities. This might necessitate the application of insecticides as described in section 3.1. An important prevention measure to reduce the risk of mass developments is the establishment of mixed plantations, as described in section 3.2, since the beetle has strong feeding preferences (Kolehmainen, 1995).

Two common pests on poplar, which cause stem rather than leaf damage, are *Saperda populnea* L. (small poplar longhorn beetle) and *Saperda carcharias* L. (large poplar longhorn beetle). In particular the former used to be a frequent pest of young poplar stands in the 19th century in Germany (Schwenke 1974). Its larvae develop inside young shoots. Their presence is noticeable by stem galls developing around the spot where the larva bore into the stem (Fig. 6). However, similar galls are caused by other species as well (see next paragraph on *Paranthrene tabaniformis*). In contrast to *S. populnea*, *S. carcharias* only infests trees which have already reached a certain dimension. Its larvae bore into the lower end of the trunk foot causing great wood damage. Combating of those species is difficult as they develop inside the stem. In Germany, there are insecticides licensed to combat longhorn beetles. Another measure would be to remove infested trees (see section 3.1).

Similar damage to that done by the above mentioned longhorn beetles can be caused by two butterfly species: *Paranthrene tabaniformis* Rottenburg (dusky clearwing) and *Sesia apiformis* Clerck (hornet moth). The caterpillar of the former mainly develops inside young shoots like *Saperda populnea*. When the imago hatches, the pupae shell remains half inside the stem, half outside (Fig. 7). This makes identification easy. The species was found in several plantations in the east of Germany in relatively high densities. Another species belonging to the family of Sesiidae is *Sesia apiformis*, which takes the same position as *Saperda carcharias*. In contrast to *P. tabaniformis* it infests only trees which have already reached a certain dimension and bores into the lower end of the trunk. Lapietra and Allegro (1994) and Brown et al. (2006) examined pheromone trapping as monitoring tool and suggest management strategies.

Another type of damage which has been reported more and more frequently over recent years is the occurrence of horizontal, half or completely formed, swollen bark rings on young shoots (Fig. 8). Often several of these rings occurred on one shoot. The publication of Richter (1959) helped identify the damage as ring barking by Cimbicid sawflies (Cimbicidae). Perny and Volkl (2009) report the same damage on poplar in Austria. As a possible, initiating species *Cimbex lutea* L. and *Pseudoclavellaria amerinae* L. are named. However, no imago has been caught yet. In general, the bark injury provides, as with any bark damage, the possibility for fungal species to infest the shoot. More importantly, the damage was observed to lead to a breaking of shoots at the point of the injury. Despite the abundance of these bark rings, severe damage has not been reported so far.

Fig.6: Stem damage by *Saperda populnea*

Fig.7: Stem damage by *Paranthrene tabaniformis*

Fig.8: Stem damage by Cimbicid sawflies

In the framework of identifying potential pest species for SRC, the development of *Lymantria dispar* L. (gypsy moth) on willow and poplar was examined, although the species has hardly been found in SRC in Germany. The Gypsy moth, however, is a severe forest pest species known for its tendency to mass developments and its polyphagous feeding (Shields et al., 2003; Hoch et al., 2001). Other *Lymantria* species are reported as pests in Asia. The experiment was conducted in the laboratory, where larvae were fed with either willow or poplar. Their wet weight was determined daily. The results showed that *L. dispar* is easily able to successfully develop on willow. In contrast, the larvae raised on poplar gained weight only very slowly and none of the larvae pupated (Fig. 9). These results seem to make poplar plantations a less attractive site for *L. dispar*. However, at the same time as these laboratory investigations a mass development of *L. dispar* occurred in Saxony on a former mining area in an area with sea buckthorn (*Hippophae rhamnoides* L.). The older instars then moved on to nearby poplars, completely defoliating the trees. Thus, the occurrence of the gypsy moth in the close vicinity of poplar SRC also threatens the plantation. In the forest, the species is monitored using pheromone traps and counting egg masses. Insecticides to combat the butterfly exist.

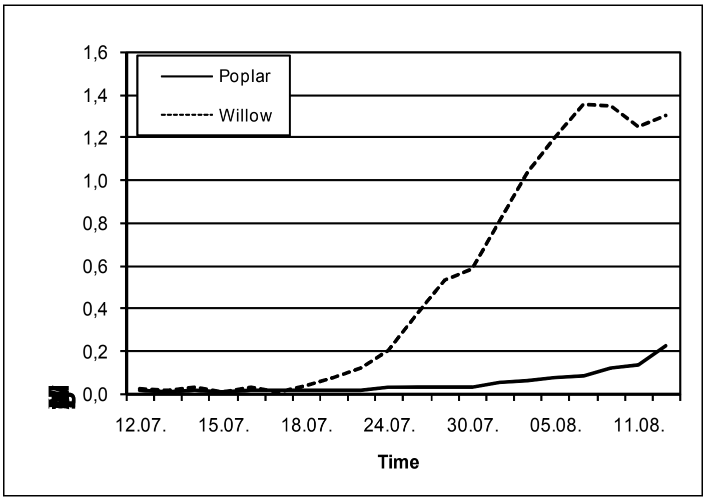

Fig. 9: Development of wet weight per individual of *Lymantria dispar* larvae raised on willow and poplar

2.2 Main insect pests on willow (*Salix* sp.)

Compared to poplar, willow plays a minor role in SRC in Germany. It usually yields less, but shows a higher survival rate. In other countries, such as Great Britain or Sweden, willow is the most used tree species for SRC. Their main pest species is the leaf beetle *Phratora vulgatissima* L. (blue willow beetle) which is able to severely damage plantations by completely defoliating the plants (Fig. 10). It often occurs in high densities and thus seems to play the same role on willow as the red poplar leaf beetle on poplar. Comparisons between *Phratora vulgatissima*, *Phratora vitellinae* and *Chrysomela populi* have already been made in the section on *Phratora vitellinae* as a poplar pest. A lot of research has been done on this species. As described in section 3.2, strong feeding preferences triggered by the concentration of phenolic glycosides were found (Peacock et al. 2002, Kendall et al. 1996). As described in section 3.2, it was shown that mixed plantations have an important influence on the beetle's population growth and spread and thus play an essential part of integrated pest management (Peacock and Herrick, 2000).

A species which locally caused severe damage on a willow plantation in Germany was the longhorn beetle *Oberea oculata* L. (eyed longhorn beetle). In the second year of the plantation, which stood quite isolated from other willows, tiny bark injuries were observed on a lot of shoots only a few centimetres above the soil. When these shoots were harvested for research purposes in winter they were hollow inside, except for some small splints of wood. About 2.5 cm long, white longhorn beetle larvae were found to have caused this damage (Fig. 11). They had infested 40% of all shoots of suitable size. A few of these shoots were already broken down at the initial bore hole of the larvae as consequence of the hollowing. The further development of this damage could not be observed due to the harvest. The larvae were bred in the laboratory and identified as the above mentioned species. The beetle emerges through a hole in the stem causing another possible breaking point and giving way for the infestation with fungal species. To combat *O. oculata*, the same would apply as for *Saperda populnea* on poplar.

Other species frequently observed and reported as pest on willows were common sawflies (Tenthredinidae). Their larvae feed gregariously on leaves. Mainly larvae of the genus *Nematus* were found, which display a characteristic body position when being disturbed (Fig. 12). Larvae of the genus *Rhogogaster* also were found, but less frequently. As imago only *Rhogogaster viridis* L. was recorded, however, solely in poplar plantations. Interestingly preying on a *Chrysomela populi* prepupa was observed once. In this development stage the leaf beetle does not actively emit defence secretion any more. However, *Rhogaster viridis* could not be used as a control agent for *Chrysomela populi*, as their larvae are SRC pests. Perny and Steyrer (2009) describe a mass development of *Nematus pavidus*

Serville on willow in Austria, with the insect showing strong feeding preferences among the varieties. Searching for cocoons in the soil in spring can help predicting populations. Insecticides for combating common sawflies exist.

Fig. 10: Leaf damage by *Phratora vulgatissima* (Photo: Enerpedia)

Fig. 11: Larva of *Obera oculata* inside a shoot

Fig. 12: Leaf damage by *Nematus* sp. larvae

2.3 Main insect pests on black locust (*Robinia pseudoacacia*)

As a neophyte, black locust in Germany is associated with only a low number of insects. This is an advantage in terms of producing woody biomass. Furthermore, the high drought tolerance of black locust is beneficial for establishing SRC on drier sites. However, the planting of this species is often dismissed by nature conservationists in a wide range of protected areas. As there has been a vivid discussion on the effects of SRC from nature conservation's point of view, the planting of black locust might be a contentious issue for some areas at least.

In Germany black locust is mainly used for SRC on dry sites in the east and north of the country. South of Berlin, 105 ha with black locust have been established over the last two years. The investigations on this site revealed two main pest species on black locust.

In particular in early summer, leaves showed regularly shaped, round leaf edge damage (Fig. 13). At the same time different species of *Phyllobius* sp. were found. Later in the year, *Sitona gressorius* and *Sitona griseus* also occurred. Both genera are known for causing the mentioned damage. Although the density of these weevils was partly high and the damage quite conspicuous, no long term damage was observed. The more leaf biomass the trees developed over the course of the year, the smaller the influence of the beetles became. Furthermore, the population peak is usually in early summer; from then on their number decreases. Accordingly, we found the heaviest leaf damage in June.

Another frequent form of damage on black locust were leaf edge galls: usually two to three per leaf (Fig.14). These galls are caused by *Obolodiplosis robiniae* (Haldeman), the black locust gall midge. The insect is native to North America and an invasive species in Europe. It was first observed in Europe in Italy in 2003 (Navone and Tavella, 2004) and then spread through the whole continent. The first evidence from Germany stems from 2006 (Hoffmann et al, 2007). Toth et al. (2009) classify *O. robiniae* as a common species with a high potential to become an important pest. However, this status has not been reached yet.

Fig. 13: Leaf edge damage by weevils

Fig. 14: Leaf edge galls by *Obolodiplosis robiniae* as seen on the leaf under side

3. Pest management strategies

Pest management strategies can be generally divided into eradication and prevention measures, with the former taking place after the pest infestation, the latter being an integrated part in the overall management of the plantation. The better prevention measures are performed, the less likely eradication measures will have to take place.

3.1 Eradication measures

Eradication measures are measures to fight the attack of a pest species. The main options are the removal of the infested plant and the use of insecticides. Another possibility would be the release of artificially bred predators. Although this is common practice in greenhouses in Germany, for example the release of *Cryptolaemus montrouzieri* (Mealybug ladybird) to fight mealybugs, what is not feasible in the outdoors yet. The predator released would have to be absolutely host-specific and it would have to be certain that it does not migrate from the plantation.

The removal of infested plants is a measure mainly feasible in smaller plantations when the pest only occurs in low numbers. It is, for example, used to fight stem damaging long horn beetles such as the Asian long-horned beetle *Anoplophora glabripennis* Motsch. (Smith et al. 2011). This species has not been recorded in SRC in Germany yet. The removal of plants to fight leaf eating pests is not efficient. Thus, this measure is only of very limited use.

The most common eradication measure in SRC in Germany to combat insects today is the use of insecticides. In contrast to agricultural crops it is, however, not applied preventively, and its use is generally kept as low as possible. Furthermore, there is a legal problem with the use of insecticides in SRC in Germany. Their use in general is regulated in the annually published ‘Plant Protectant Catalogue’ (Pflanzenschutzmittelverzeichnis) and each product is licensed to be used on certain crops and a certain type of land (i.e. agricultural land, forest, orchards). The establishment of SRC on agricultural land poses a problem, as the catalogue part to be used in agriculture does not yet have a tree species crop. As a consequence, the permission for an application of insecticides to SRC plants has to be requested from the responsible authority.

In addition, the effect of insecticides on common SRC insect pests has not been tested yet. Therefore a laboratory screening of various insecticides was conducted on larvae and imagos of the main insect pest species in Germany, the red poplar leaf beetle (*Chrysomela populi*). Insecticides from all common agent groups were chosen, also including new ones such as semicarbazones, and also focusing on biological agents. Altogether nine different products representing eight different agents were tested (Tab. 1).

The liquid insecticides were applied to a single poplar leaf which was put into a glass jar after the substance was dried. Three imagos or four larvae were put into each glass jar and left there feeding for 24 hours. Individuals surviving this period were held on untreated foliage to simulate the migration to pests to untreated plantations. Altogether 20 larvae and 18 imagos were tested per insecticide. The study lasted 17 days (imagos) and 18 days (larvae), respectively.

Table 1. Overview of the agents tested on *Chrysomela populi* larvae and imagos in the laboratory (* = biological agents)

Agent	Agent group
azadirachtin*	azadirachtin
alpha-cypermethrin	pyrethroids
*Bacillus thuringiensis var. tenebrionis**	*Bacillus thuringiensis*
lambda-cyhalothrin	pyrethroids
metaflumizone	semicarbazones
pyrethrin* (+ rapeseed oil)	pyrethrins
spinosad*	spinosyns
thiacloprid	neonicotinoids

Four of the tested insecticides are synthetic, the others are biological: azadirachtin comes from the seeds of the neem tree (*Azadirachta indica* L.), *Bacillus thuringiensis* is a bacterium that produces toxins inside the pest's body, spinosad is a toxine derived from a soil dwelling bacteria and pyrethrins are contained in the seed cases of the flower *Chrysanthemum cinerariaefolium* L. In Germany these agents are permitted in organic farming.

Figure 15 displays the number of feeding imagos over the test period. For the evaluation of insecticides the time when feeding stops permanently is more important than the actual time of death of the pest. As can be seen, the agents had very different effects on *Chrysomela populi* imagos. Except for metaflumizone, all synthetic agents very quickly caused a feeding cessation. Out of the four biological agents, spinosad and pyrethrin proved to be very effective. The limited effects of Azadirachtin and *Bacillus thuringiensis* were expected and result from the mode of action. *Bacillus thuringiensis* in Germany is only licensed to be used for the combat of larvae.

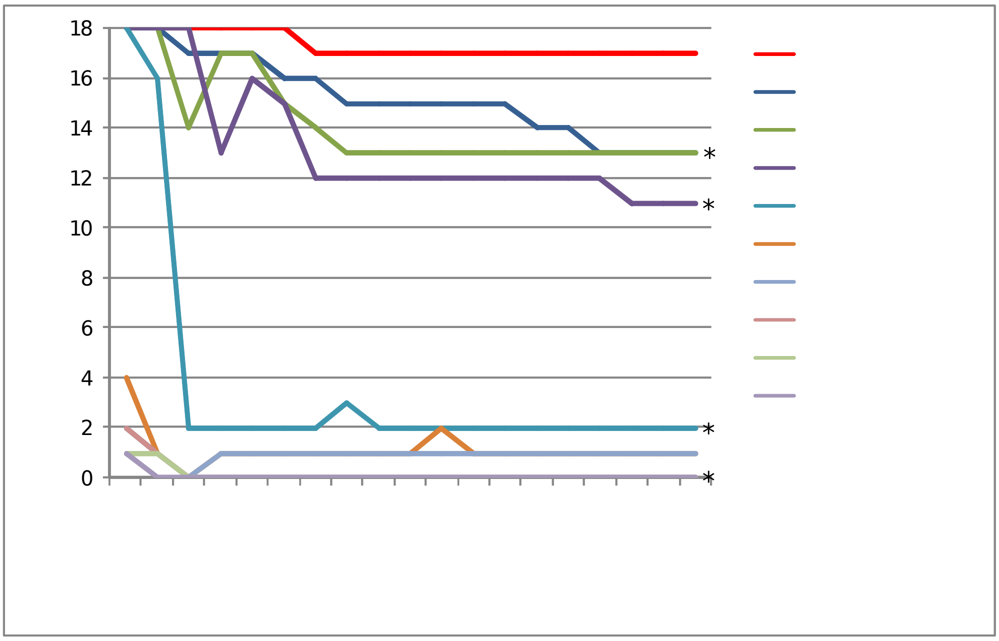

Fig. 15: Number of feeding imagos over the test period (* = biological agents)

Regarding the synthetic agents, the results on larvae were the same as on imagos. However, the results for the biological agents differed. Spinosad caused a very quick feeding cessation and death of all larvae. Azadirachtin also had the same final effect, but it acted much more slowly, displaying a delay of ten days. *Bacillus thuringiensis* and pyrethrin were less effective than the other two biological agents: the former left 20% of the larvae to successfully develop into beetles at the end of the test period, the latter 30%. However, Kühne et al. (2010) reported very good results from a combination of *Bacillus thuringiensis* and azadirachtin used in a time shift mode to combat *Leptinotarsa decemlineata* (Colorado potato beetle), a relative of *Chrysomela populi*.

The test results can be transferred to all others Chrysomelid beetles, and partly also to other leaf eating insect pests such as butterflies. Only the tested *Bacillus thuringensis* strain solely affects Chrysomelid beetles. For combating butterflies, a different strain has to be used.

3.2 Prevention measures

More important than eradication measures are prevention measures; measures that are included in the general management of the plantation to help reduce the risk of the occurrence of a mass development of insects or other biotic problems. They play the key role in a successful pest management strategy.

For SRC there are three main things to imply on an immediate short-term level. First of all, optimal conditions when establishing the plantation have to be certain: the optimal site, choice of tree species and varieties, soil preparation, cutting quality, planting quality, time of planting etc. This is vital for the further performance of the area and brings benefits for the whole life cycle. The year of establishment will require the most input into a plantation. It is the year when the plantation is most sensitive to insect pests and other biotic risk factors. A similarly sensitive phase calling for increased attention for pests is the year after the harvest.

Another very important point is to ensure the highest possible biodiversity in the plantation like using as many different tree species and varieties as possible. This will guarantee that monophagous insects only damage a part of the plantation and furthermore it will provide a habitat for different species of predators. According to the resource concentration hypothesis, insect pests are less likely to occur in high densities in small patches of their host plants. Peacock and Herrick (2000) could confirm this for the situation of SRC planted as a mixture of different varieties or as a monoculture. Using the example of *Phratora vulgatissima*, the main pest species in willow SRC, they found lower colonization in and increased emigration from the mixtures compared to the monocultures, since mobile insects lose time when trying to find a new host plant. The mixtures showed lower beetle densities, damage and oviposition. As an ideal plantation design, the authors suggest the mixture of five varieties with at least one with a low susceptibility to the insect in question, planted as a random mixture. However, in practice the different growth cycle of varieties or the size of the area available may limit the possibilities.

Last but not least the plantation has to be checked regularly by competent staff to make sure that the infestation with insect pests is detected early and appropriate measures are developed.

4. Conclusion

SRC is established to produce biomass. High yields, however, are only achievable under optimal conditions. Observations over a number of years have shown that insect pest species can pose a severe threat to SRC and are able to cause massive yield losses. Many preventative measures exist to reduce the influence of these pests and the risk of mass developments. The application of insecticides can be an appropriate instrument to combat some of the most relevant pest species. In the long term, breeding programmes ensuring the availability of a high number of different varieties have to be developed. Results on food preferences could be included here. Research in the field of insect pest species in SRC is also essential for guaranteeing successful management of SRC in the future.

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Appraisal of agroforestry landuse systems prevalent on farmers' owned lands for their carbon sequestration potential in Mid-Himalaya Region of Himachal Pradesh, India.

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Introduction

Himachal Pradesh is one of the Western Himalayan states of Indian Himalaya situated between 30o22'40" - 30o12'40"N latitude and 75º47'55"- 79º4'20" E longitude. The altitudinal variation ranges from 350 to 6816 msl. Farming systems except meadows and temperate pastures in high mountainous regions are predominantly tree based comprising fodder, fuel, small timber and fruit species. These trees naturally occurring and maintained by the farmers on their private and common lands besides supplying the minor and occasional needs of land holders are the core asset of regions'natural environment. Different tree species in most cases of forestry, scattered all over the agricultural landscapes including the pasture lands in low and mid hills presents an array of natural and manmade agroforestry systems. Man made agroforestry systems are discernibly fruit based. This kind of landuse provides unlimited potential for sequestering carbon not only as an option to mitigate the global climate change but also to the reciprocal benefit of farmers and potential investors involved in carbon management under Clean Development Mechanism (CDM).

Kartha (2001) highlighted that approximately 120 billion tonnes of carbon is absorbed annually through photosynthesis and comparable amount is released through respiration and decomposition. Kursten, (2000) stated that by including trees in agricultural production systems, the amount of carbon stored in lands devoted to agriculture is increased while still allowing for the growing space of food crops. The amount of biomass or the carbon that is harvested and exported (labile carbon) from the system is relatively low in relation to total productivity of the trees. Verma (2005) also emphasized that unlike in plantation and other monoculture systems, agroforestry seems to have unique advantage in terms of carbon sequestration. The amount of carbon sequestered largely depends on the agroforestry system/model put in place. Other factors influence carbon storage in these systems includes tree species and system management.

Concern about rising carbon dioxide has created considerable interest regarding the sink potential of soil organic carbon. Indian soils are largely carbon depleted but can be brought back to their native carbon-carrying capacity by reforestation including agroforestry. Wastelands in India cover more than 100 million ha. of which 70 per cent are carbon degraded. Promoting agroforestry in these lands is highly desirable not only for carbon but also to meet the material and environmental aspirations. Selection of tree species for bringing carbon depleted lands back to their native carbon-carrying levels should base on land category. Short rotation forest tree species for crop lands and long rotation for bund and block planting on fallow lands are beneficial. However, a mix of short and long rotation multipurpose tree species to establish silvipasture systems on private or community grazing lands will be highly suitable.

Landuse can be a source or sink for carbon depending upon the structural composition and tree/crop management experienced by the system. The proportion of carbon stored in landuse varies widely depending on their components, management and climate of the region Therefore, a comprehensive information on the spatial and temporal distribution of landuse, is pre-requisite for understanding the carbon flux by local estimates. Hence, the current studies were undertaken to generate information on net biomass carbon uptake and emissions from agroforestry landuse systems and climate change mitigation and carbon credit production potential of different landuse systems on farmers private land.

Methods

To appraise the carbon sequestration potential of agroforestry landuse systems on farmers' own lands in Kwalkhad Watershed (H.P.) India, attributes viz. structural and functional composition of agroforestry systems, crop and tree management practices and carbon stocks based on biomass produced were studied. Carbon stocks were based on above/below ground biomass and soil carbon in 0-20cm and 0-40cm soil layers. The study site attributes are presented in Table 1.

Table 1. Locality factors of the Kwalkhad watershed the study site in mid Himalayan region of H.P. India

Area	1646.00 ha
Latitude	$30^0$45'00" to $30^0$54'45" N
Longitude	$77^0$03'15" to $77^0$13'35" E
Altitude	900 to 2100 masl
Climate type	Sub-humid sub-tropical
Mean annual temperature	19.80^{0}C
Mean annual precipitation	1150 mm
Soil type	Alfisols, mollisols, inceptisols and entisols
Texture	Sandy loam
Parent material	Ferromegnesium shales and dolomitic limestones
Soil pH	a) to 7.2

Data collection

The sample area of study was selected through random sampling. First stage comprise complete enumeration of villages in Kwalkhad Watershed and selection of target villages/sites at random for the purpose of study. Second stage comprise complete enumeration and listing of farmers/households of each target village.

Identification of agroforestry land use systems was based on the structure (nature and arrangement of components) and function(output) of the landuse. Recognizing the structure and function of different systems, their primary and secondary components were identified. The component occupying the greater part of land area under an agroforestry system and performing the primary function i.e. production of foods, fruits, fodder, timber, etc. needed by the land holder was termed as primary. Accordingly, the secondary components were delineated. Annual crop and tree management practices in vogue viz. cereals; pulses, vegetables their cropping sequences/pattern, type of tree species present and their number per unit area, etc. were recorded.

All non-arable lands (locally-"ghasnis") put to the use of fodder production for livestock rearing were put under the landuse grassland. Abandoned lands by definition are assumed not subjected to ongoing human intervention (of significance to carbon stocks) after abandonment (IPCC, 1996).

Carbon inventory was prepared according to Revised IPCC 1996 Guidelines for GHG inventory and also the IPCC Good Practice Guidance. Above ground biomass of trees was estimated by non-destructive methods for different plant parts viz. stem, branch and leaf. The tree biomass was converted into carbon by a factor of 0.45 (Woomer, 1999). Crop biomass and grass biomass was estimated using 1x1m quadrates by destructive method. Below ground biomass of trees was calculated by multiplying above ground biomass with a factor of 0.25 for broad leaved species and 0.20 for coniferous species (IPCC, 1996). In case of annual crops and grasses below ground biomass was calculated by multiplying with a root: shoot ratio of each crop species.

For soil carbon, soil profiles of 20x20x40cm was dug for each identified landuse system and composite samples were obtained for two soil layers i.e. 0-20cm and 20-40cm. Bulk density was determined by weighing bottle method (Singh, 1980) whereas organic carbon using Walkley and Black (1934) method. The soil carbon inventory expressed as mega grams per hectare ($Mgha^{-1}$) for each soil layer was computed using the method given by Joao Carlos *et al.*(2001). The data so obtained were analyzed using statistical tests like Fisher's test and analysis of variance technique – one way classification of data.

Results and discussion

Prevalence of agroforestry systems in kwalkhad watershed: Based on the structural composition and functional output produced, five agroforestry systems with multiple tree-crop components and three single crop based landuse systems preferred by the farmers on their lands were identified. Agri-silvi-horticulture, agri-horti-silviculture, agri-silviculture, agri-horticulture and silvi-pasture were among the agroforestry whereas pure agriculture, pure grassland and abandoned land were among the single crop based landuse systems (Table 2). The extent of landuse showed the preference of farmers toward a particular landuse. On the basis of number of system units present agri-silvi-horticulture was found to be widely prevalent in the area. The second system in the order of preference was silvi-pastoral followed by agri-horti-silviculture. Leaving apart abandoned lands pure agriculture was least practiced. Thus, it is quite discernible that agroforestry is the most common landuse of this region.

On considering the unit land area, silvi-pasture system ranked first followed by abandoned lands. Next to these two landuse systems were agri-horti-silviculture and agri-silvi-horticulture. Agri-horticulture system had the least land size per unit preceded by pure grassland and pure agriculture. The study thus showed that farmers in the region integrate forest and fruit tree species with agricultural crops very commonly for multiple outputs.

The preferred forest and fruit tree species maintained by the farmers in different agroforestry systems are given in Table 3. Predominant forestry species were *Acacia catechu, Celtis australis* & *Grewia optiva* whereas *Prunus aremeniaca* and *Punica granatum* were the fruit species. The density of trees both forestry plus fruit trees, varied from 38 in agri-silviculture to 110 in agri-horti-silviculture. The tree density per hectare in ASH, AH and SP was 96, 69 and 90, respectively. This is suitable for mid hills region of Himachal Himalayas of India where tree based and terraced farming is practiced.

Table 2. Prevalences and land area occupied by different landuse systems in Kwalkhad watershed located in mid Himalayan region of H.P. India.

Land use system	System units (Nos.)	Land area (ha)	
		Range	Mean
Agri-silvi-horticulture (ASH)	23	0.08-2.00	0.69
Agri-horti-silviculture (AHS)	12	0.12-1.60	0.79
Agri-silviculture (AS)	05	0.36-0.72	0.49

Agri-horticulture (AH)	05	0.04-0.80	0.33
Silvi-pasture (SP)	16	0.08-5.60	1.74
Pure agriculture (PA)	04	0.19-0.77	0.46
Pure grassland (PG)	11	0.08-1.60	0.45
Abandoned land (AL)	03	2.40-1.04	1.45

Table 3. Preferred tree species and their density (per ha.) in different agroforestry systems of Kwalkhad watershed.

S. No.	Agroforestry system	Forestry species (No.)	Total No.	Fruit species (No.)	Total No.	G. Total (Forest + fruit Trees)
1.	Agri-silvi-horticulture	*Acacia catechu (3), Dalbergia sissoo (3), Celtis australis (19), Ficus spp. (9), Grewia optiva (17), Quercus leucotrichophora (4), Toona ciliata (9)*	64	*Prunus armeniaca (10), Punica granatum* (200)	32	96
2.	Agri-horti-silviculture	*Albizzia chinensis (1), C. australis (16), G. optiva (9), T. ciliata (6)*	32	*P. armeniaca (4), Citrus spp. (5), Pyrus communis (25), Purnus saliciana (6), P. granatum* (38)	78	110
3.	Agri-silviculture	*C. australis (8), Ficus spp. (9), G. optiva (13), Melia azedarach (2), Pyrus pashia (2), T. ciliata (2), Ulmus villosa (2)*	38	---	-	38
4.	Agri-horticulture	---	-	*Emblica officinalis (24), Citrus spp. (24), P. armeniaca (15), P. saliciana (3), P. granatum (3)*	69	69
5.	Silvi-pasture	*catechu (29), C. australis (1), Pinus roxburghii (49), Pyrus pashia (3), Q. leucotrichophora (8)*	90	---	-	90

The major crop components were cereals, pulses and spices in all the systems. Among the cereals- maize, wheat whereas in vegetables- tomato and pea were the most common primary functional units. Vegetable crops like colocasia, capsicum, beans, chilli and spices like turmeric, ginger, garlic formed the secondary crop component in all the system in terms of area allocated to these crop units by the farmers.

Biomass dynamics: In agroforestry systems total biomass production is invariably influenced by crop species put in place, forest and fruit tree species involved, their density and management to produce the desired output. Farmers' need, on the other hand determines the amount of produced biomass removed/exported periodically out of the system. This labile biomass pool, in turn, determines the size of non-labile or retained biomass pool of an agroforestry system. Data in Table (4) shows the mean biomass accumulated, removed and retained by different landuse systems. The values include both above and belowground biomass.

Table 4. Mean accumulated, removed and retained biomass (tones ha^{-1}) by different land use systems in Kwalkhad watershed

Land use system	Accumulated	Removed	Retained
Agri-horti-silviculture (AHS)	32.01	20.29	11.81
Agri-silviculture (AS)	23.65	15.19	8.46
Agri-horticulture (AH)	26.99	20.32	6.67
Silvi-pasture (SP)	7.48	4.17	3.31
Pure agriculture (PA)	18.31	13.58	4.74
Pure grassland (PG)	2.74	2.26	0.48
Abandoned land (AL)	3.57	0.00	3.57
F value	**27.94**	**23.50**	**17.05**

Accumulated, removed and retained biomass

There was significant difference in biomass values of the different land use systems. Maximum accumulated biomass was in ASH system with a value of 32.85 t ha^{-1}. However the AHS system (32.01 t ha^{-1}) was found to be statistically at par with ASH. This was followed by AH (26.99 t ha^{-1}) & AS (23.65 t ha^{-1}). Minimum accumulated biomass was observed in pure grassland (2.74 t/ha), which was at par with abandoned land (3.57 t/ha). The above results revealed that all the agroforestry systems on arable lands showed higher biomass accumulation than non-arable landuse system viz. SP, AL and PG.

Maximum biomass (20.32 t ha^{-}1) was removed from AH system which was at par with AHS system. ASH, AS, PA, SP, PG and AL followed descending order. The higher removal from the AH system may be because of the presence of vegetable (root) crops being dominant component in the system along with fruit trees. The per hectare retained biomass in different land use systems was in the order of: ASH > AHS> AS > AH > PA > AL > SP > PG with the respective values of 13.03 > 11.81 > 8.46 > 6.67 > 4.74 > 3.57 > 3.31> 0.48 t/ha. The results indicated that the arable agroforestry systems were higher biomass retainer than non-arable land use systems.

These results help explaining in quantitative terms the influence of land use system's structure, composition and management on the biomass accumulation, removal and retention. The similar observations were recorded by Kumar (2003) that AHS system over AS system produced higher biomass in Western Indian Himalaya. Deshmukh (1998) similarly reported that management

practices also affect the biomass production of fodder trees grown under agroforestry. He found that pollarding height affects the biomass production of shoots and leaves. Nayak (1996) found the above ground biomass to be influenced because of the species and its density.

Carbon dynamics Biomass carbon sequestered emitted and mitigated (Table 5) by different landuse systems in Kwalkhad Watershed has been discussed in this section.

i)Carbon sequestered (Mg ha^{-1}): Agri-silvi-horticulture system showed the highest amount of carbon sequestered which was closely followed by AHS. The respective values for these two systems were 14.78

and 14.45. Silvipasture system, abandoned lands and pure grasslands sequestered 3.36,1.60 and 1.23 Mg ha^{-1} of carbon. These three are mainly non-arable landuse systems. Their comparison with systems on arable lands viz. ASH, AHS, AS, AH and PG for sequestering carbon evidently showed the higher potential of later systems called agroforestry systems.

ii) Carbon emitted: Emitted carbon or the quantity of carbon exported out of the different landuse systems was maximum or almost equal for AH (9.14) and AHS (9.13). The ASH system followed the above two systems with the value of 8.92 (Mg ha^{-1}). The AH and AHS systems showed the higher carbon emissions because of their larger labile carbon pool based on species mix. Fruit crops and vegetable crops dominated their system components which contributed higher removal of harvestable biomass. Further SP system contributed lesser emissions over AS. The plausible reason was that former system contained *Pinus roxburghii* and *Acacia catechu* as system components. The biomass of these species was the least used by the farmers. On the other hand tree components in later system were *Grewia optiva* and *C. australis*. The two species are heavily lopped for regular needs of fodder and fuelwood.

Abandoned land was given the value zero. Since no amount of carbon was intended to be harvested or actually removed by the farmers from this system. Pure grassland and silvi-pasture systems emitted 1.02 and 1.88 Mg ha^{-1} respectively, both showed the minimum emissions but the amount of C sequestered by these systems was also minimum over the remaining landuse system.

Table 5. Current biomass carbon sequestration, emission and mitigation by different land use systems in Kwalkhad watershed.

Land use systems	**Mg ha^{-1}**		
	Sequestered	**Emitted**	**Mitigated**
Agri-silvi-horticulture (ASH)	14.78	8.92	5.86
Agri-horti-silviculture (AHS)	14.45	9.13	5.32
Agri-silviculture (AS)	10.64	6.84	3.81
Agri-horticulture (AH)	12.15	9.14	3.01
Silvi-pasture (SP)	3.36	1.88	1.49
Pure agriculture (PA)	8.24	6.11	2.13
Pure grassland (PG)	1.23	1.02	0.21
Abandoned land (AL)	1.60	0.00	1.60
F value	**27.94**	**23.50**	**17.05**

iii) Carbon mitigated: Agri-silvi-horticulture system with highest mitigated carbon of 5.86 (Mg ha^{-1}) ranked first among all other landuse systems. Pure grassland ranked the last. Different landuse system studied in terms of carbon mitigation observed the descending order of: ASH> AHS> AS> AH>PA>AL>SP>PG.

It was deduced from the results that the carbon statistics of different agroforestry systems were influenced by the nature of components and also their composition. Previously, Albrecht & Kandji (2003) reported that carbon variability in plant biomass can be high within complex agroforestry systems. Productivity of system depends on several factors including the age, structure and the system management. Verma *et. al* (2009) previously reported that agroforestry systems helps in locking high amount of carbon and their CO_2 mitigation capacity could be enhanced by substituting suitable tree and annual crop species in existing agroforestry systems.

Carbon pool inventory (Mg C ha^{-1})

The carbon pool inventory of different land use systems included soil organic carbon pool and the net carbon stock in plant biomass (Table 6). The soil organic carbon pool represented two soil layers of 0-20 cm and 0-40 cm. In 0-20cm soil layer abandoned landuse exhibited the highest total carbon pool. It was followed by SP and ASH systems. Lowest carbon pool was in pure agriculture. On extending the soil layer upto 40 cm. total carbon pool behaved similar as above.

Table 6. Carbon pool inventory (Plant and soil) of different land use systems upto 0-20 cm or 0-40 cm soil layers in Kwalkhad watershed of H.P., India.

Land use system	Carbon (Mg ha^{-1})						Plant : soil C Pool
	0-20 cm			0-40 cm			
	Plant	Soil	Total	Plant	Soil	Total	
Agri-silvi-horticulture (ASH)	5.86	52.14	58.00	5.86	95.46	101.32	16.29
Agri-horti-silviculture (AHS)	5.32	46.56	51.88	5.32	84.14	89.46	15.81
Agri-silviculture (AS)	3.81	50.58	54.29	3.81	92.65	96.36	24.31
Agri-horticulture (AH)	3.01	47.73	50.74	3.01	90.07	93.08	29.92
Silvi-pasture (SP)	1.49	63.54	65.03	1.49	115.45	116.94	77.48
Pure agriculture (PA)	2.13	35.93	38.06	2.13	65.43	67.56	30.71
Pure grassland (PG)	0.21	51.67	51.88	0.21	80.15	80.36	381.66
Abandoned land (AL)	1.60	86.73	88.33	1.60	164.41	166.01	102.75

Further comparison of plant and soil carbon pools revealed that in all the landuse systems size of soil carbon pool was manifold than the plants. For 0-40 cm. soil layer, carbon stock in soil exceeded carbon stock in plant by a factor of 15.81 for AHS which was lowest among all the landuse systems. The trend was similar and maximum factor was 381.66 for pure grasslands. In general non-arable landuse systems viz. SP, PG and AL showed much larger factors than arable landuse system viz. ASH, AHS, AS, AH and PG. Globally, carbon stock in the soils exceed carbon stocks in vegetation by a factor of about 5. The ratio ranges from 1:1 in tropical forests to 5:1 in boreal forests and by much larger factors in grasslands and wetlands (IPCC, 2000).

The present results further indicated that in agroforestry systems where regular tilling of soil for seasonal crop production is undertaken, soil carbon pool gets depleted. Previously Lal *et. al*. (1998) also reported decrease in soil organic carbon pool due to cropping practices in Nigerian soil where cropping decreased soil organic carbon by 25-60 per cent for the top 0-5 cm. soil. Contrary to above conditions, higher carbon pool under AL, PG & SP systems may be due to regular addition of biomass on the soils over the years.

Carbon mitigation potential

All the land use systems showed higher relative carbon mitigation potential than pure agriculture (Table 7). For the soil layer 0-20 cm, the relative carbon mitigation potential ranged from 1.33-2.32. The lowest value was for AH and the maximum for abandoned land.

Relative carbon mitigation potential of AL was 2.32 times higher than pure agriculture followed by SP, ASH, AS, PG=AHS and AH with the values of 1.71, 1.52, 1.43, 1.36, 1.36 and 1.33, respectively. Overall for 0-40 cm soil layer, different land use systems showed slightly higher carbon mitigation potential values except for PG.

Table. 7: Relative carbon mitigation potential of different landuse system with respect to Pure agriculture in kwalkhad watershed.

Land use system	**Carbon mitigation potential**	
	Upto 20 cm soil layer	**Upto 40 cm soil layer**
Agri-silvi-horticulture (ASH)	1.52 (+ 0.52)	1.50 (+ 0.50)
Agri-horti-silviculture (AHS)	1.36 (+ 0.36)	1.32 (+ 0.32)
Agri-silviculture (AS)	1.43 (+ 0.43)	1.43 (+ 0.43)
Agri-horticulture (AH)	1.33 (+ 0.33)	1. 38 (+ 0.38)
Silvi-pasture (SP)	1.71 (+0.71)	1.73 (+ 0.73)
Pure agriculture (PA)	1.00 (± 0.00)	1.00 (± 0.00)
Pure grassland (PG)	1.36 (+0.36)	1.19 (+ 0.19)
Abandoned land (AL)	2.32 (+ 1.32)	2.46 (+ 1.46)

Carbon credit production potential

The Kwalkhad watershed covered 368.75 ha of total land under identified agroforestry systems. Maximum land area of 178.72 ha was under SP system. It was followed by ASH, AHS, AS and AH with respective values of 102.04, 61.11, 16.22 and 10.66 ha (Table 8).

ASH system in the total land area covered contributed maximum in biomass carbon mitigation 598.00 Mg. The different land use systems in terms of their carbon mitigation value followed the order of : AHS > SP > AS > AH with respective values of 325.10, 266.30, 60.18 and 32.09 Mg. The

total carbon mitigated by these land use systems was 1281.67 Mg. These trees species maintained on agricultural lands do not constitute the essential component of Production system but are additional. Farmers, generally meet the fodder and fuel wood needs from the lopped parts of trees whereas small timber on harvesting occasionally few trees at a rotation of 30-40 years. Commercial felling is never practised nor do there occur a situation of pressure on adjacent resources. Therefore, conditions like additionality and no leakage under CDM projects met inherently.

The total carbon credits likely to be earned from the Kwalkhad watershed with the use of present agroforestry systems were estimated as 4699. The highest number was from ASH system i..e 2192. ASH system produced the maximum number of carbon credits i.e. 21.49 ha^{-1} whereas SP system the minimum (5.46 ha^{-1}). These findings are constrained with actual age of trees. Tree measurements have shown these tree species in the age group of 15-25 years. Therefore, current carbon mitigation potential and number of carbon credits produced is 'likely' possible over an average time span of 20 years.

Recognizing the imperatives of carbon management in mid-himalayan region, World Bank on May 22, 2011 signed an agreement with the Government of Himachal Pradesh (H.P.) for World's largest and India's first CDM Project covering an area of 4003.07 ha. The agreement between International Bank for Reconstruction and Development. World Bank Bio-carbon Fund and H.P. Government would be in force till December, 2018. This project is linked to an ongoing mid-himalayan watershed management project with an objective to sequester carbon by expanding forestry plantations on degraded lands spread across 10 out of 12 districts of the State. The carbon revenues have been calculated at US$ 5 per carbon credit.

Table. 8: Carbon credit production potential of different agroforestry systems in Kwalkhad watershed.

Land use system	Estimated total area (ha)	Mitigated carbon (Mg)	Carbon credits*		Value of carbon credits** €***
			Total	$Ha.^{-1}$	
Agri-silvi-horticulture (ASH)	102.04	598.00	2192.00	21.49	6576
Agri-horti-silviculture (AHS)	61.11	325.10	1192.00	19.50	3576
Agri-silviculture (AS)	16.22	60.18	221.00	13.62	663
Agri-horticulture (AH)	10.66	32.09	118.00	11.07	354
Silvi-pasture (SP)	178.72	266.30	976.00	5.46	2928
Total	**368.75**	**1281.67**	**4699.00**	**71.14**	**14097**

* 1 carbon credit = 1 ton CO_2 ; ** 1 carbon credit = **€** 3.00, **€*****=**INR 64

Conclusion

Agroforestry landuse systems existing on arable and non-arable lands owned by farmers in Kwalkhad Watershed of middle Himalayan region of Himachal Pradesh, India were appraised for carbon sequesteration and production of carbon credits. In total eight landuse system types existed in the region (agri-silvi-horticulture, agri-horti-silviculture, agri-silviculture, agri-horticulture, silvi-pasture, pure agriculture, pure grasslands and abandoned lands). Agri-silvi-horticulture system closely followed by agri-horti-silviculture system sequestered the maximum biomass carbon. (14.78 and 14.45 Mg ha^{-1}, respectively). Both of the above two systems retained carbon showing their better mitigation value than the remaining.

Total C pool in abandoned lands was highest followed by silvi-pasture and agri-silvi-horticulture system (0-40 cm). Carbon stocks in soil (0-40 cm) exceeded carbon stocks in plants by a factor of 15.81 for AHS, the lowest among all systems. The highest factor was for grasslands (381.66). Leaving apart abandoned landuse systems viz. silvi-pasture, agri-silvi-horticulture and agri-silviculture with their higher carbon mitigation potential of 1.71, 1.52 & 1.43 were more suitable landuse systems for carbon mitigation in the region. Agri-silvi-horticulture system produced maximum number (21.49) of carbon credits per hectare. The findings are constrained with exact age of trees. However, carbon mitigation potential as well as carbon credits generated from current agroforestry systems could be possible over a time span of 20 years in this region based on tree measurements. This can be enhanced further, if the systems are put to improved management regimes using scientific knowledge.

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Declining Himalayan bio-resources – a threat to farmer's livelihood

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Introduction

India representing varied ecological conditions is a rich source of biodiversity. According to Govt. of India report, biological diversity is estimated to be over 45,000 plant species and 81,000 animal species, representing about 7 per cent world flora and 6.5 per cent of world fauna, respectively. The UN Convention on Biological Diversity calls for the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of benefits arising out of the utilization of genetic resources. Short rotation forestry interventions contribute to biodiversity preservation through integrated conservation development approach. Forest degradation has caused immense losses to the plant, pollinator, crop and medicinal plant diversity especially in Himalayan Hindu Kush Tract. Ever increasing concentration of green house gases in the atmosphere, land degradation, frequent occurrence of floods and droughts, desertification and contamination of resources have become subjects of serious global concerns.

Himalayan region constitutes about 54 million ha in India. These areas are characterized by marginality, inaccessibility and fragility in addition to having high intensity erratic rainfall. Hilly areas of Himalaya provide a suitable niche for a number of agro-economic activities. During the past decade, there has been a significant decline in the forest cover in all the Himalayan hill states, except Arunachal Pradesh, Sikkim and Uttaranchal (FSI, 2009). This degradation of habitat has placed India on the top ten countries with threat to their flora. The originally forested areas have been facing more damage due to mining, encroachment, infrastructure development, annual lopping patterns, removal of woody biomass for fuel wood, trampling by free grazing animals, etc., which effectively destroy existing forests and new natural regeneration.

Short rotation forestry for improved livelihood of mountainous farmers

In a scenario of increasing pressure of surging human and livestock population, shrinking per capita availability of land, deteriorating quality of soil and water resources, acute shortage of fuel wood, fodder, timber and other tree based products, emphasis has been shifted on short rotation multipurpose tree plantations in Indian Himalayan region. Human activities such as urbanization, industrialization, automobile transportation and modern agriculture with indiscriminate use of chemicals have been causing various kinds of pollutions i.e., soil, air, water, noise, radiation, green house effects, etc. and are further threatening the balance of the ecosystem. Trees have tremendous potential not only to control soil, water, air pollution and green house gases but also improve the balance of oxygen, conserve soil, water, and biodiversity. By providing shelter and food to native birgs, insects including honey bees, they provide an invaluable pollination service to mountainous resource poor farmers in the form of enhanced productivity and provide other hive products besides large quantum of honey. Thus, these trees have the ability to meet basic multiple needs of the people.

Himalayan degraded lands

Soil erosion is the major constraint in crop production in the Himalayan region due to steep sloping topography. The desertification experienced in world's highest rainfall area of Cherapunji in Meghalaya is an example. Excessive jhum cultivation, mining and extension of agricultural activities on steep slopes are a serious threat to the Himalayan landscape. High intensity rains in the monsoon season cause excessive runoff and soil loss. On erosion prone steep slopes, about 50 per cent of the rain water is lost as runoff, carrying with it as much as 207 t km^{-1} soil loss from forest and 330 t km^{-1} from agricultural in northern Himalayan region (Sharda, 2002). The shifting cultivators area, results in loss of 18 million tons of soil. As a result, the sediment yield in different tributaries of the Himalayan rivers varies from 6.0 to 98.4 m^3 ha^{-1} $year^{-1}$. These are the major causes of low and highly variable crop productivity in the region. Land degradation has become a global problem. In past, it has been a major cause of extinction of many civilizations. In India, 57 per cent of land (187.7 million ha) is facing land degradation (148.9 million ha water erosion, 13.5 million ha wind erosion, 13.8 million ha chemical deterioration and 11 million ha physical deterioration). This is attributed to increase in human and animal population leading to excessive deforestation, grazing pressure and resource exploitation. The improper cultivation practices, non-judicious fertilizer and pesticide use, faulty irrigation and water management, growing environmental pollution due to industries and urbanization are another factors accelerating land degradation. The progressive reduction in the land/man ratio (0.08ha/head by the year 2020), increase in number of holdings (77 million in 1976-77 to present 105 million) are bound to exert conflicting demands on this finite resource challenging the survival of the society (Pathak, 2000). The supports to traditional agroforestry systems and new interventions have potential for arresting land degradation in the region. The rich biodiversity of Himalayan region needs to be protected and carefully utilized for any use. The rich bamboo and rattan diversity, orchids and medicinal plants provide scope for improved resource conservation and high economic activities.

Plant diversity and Himalayan bee flora

The data on bee flora envisaged that as many as 69 plant species including cultivated and wild flora were observed for their flower visitors (Table 1). The traditional crops like buckwheat, amaranths, etc. and wild plants like *Plectaranthus* sp., *Prunus* sp. (wild), *Prunus padam*, *Punica* sp. (wild), *Syzygium* sp., etc. have seen substantially declined in the region. The productivity of horticultural crops like apple has seen an arrest even after introduction of new cultivars. The introduction of modern agriculture and protected cultivation has expanded the monoculture in the region.

Table 1. Flora of north western Himalayan region supporting native bees population

Sr. No.	Local Name	Botanical Name	Family	Source	Flowering Period
1.	Chulai	*Amaranthus paniculatus*	Amaranthaceae	P	Sept-Oct
2.	Aam	*Mangifera indica*	Anacardiaceae	N+P	Feb-March
3.	Garna	*Carissa spinarum*	Apocynaceae	N	April-May
4.	Cornflower	*Centaurea cyanus*	Asteraceae	N+P	April-May
5..	Surajmukhi	*Helianthus annus*	-do-	N+P	June-Aug
6.	Phulnoo	*Ageratum conyzoides*	-do-	N+P	June-Sept
7.	Kasmal	*Breberis lycium*	Berberidiaceae		Mar-April
8.	Puna	*Ehretia acuminata*	Boraginaceae	N	Feb-March
9.	Simbal	*Bombax ceiba*	Bombaceae	N	Feb-March

10.	Kachnar	*Bauhinia variegata*	Caesalpiniaceae	N+P	Mar-April
11.	Taur	*Bauhinia vahlii*	-do-	N+P	Mar-April
12.	Bhang	*Cannabis sativa*	Cannabinaceae	P	July-August
13.	Bathu	*Chenopodium album*	Chenopodiaceae	P	June-Aug
14.	Cosmos	*Cosmos sulphureus*	Compositae	N+P	Aug-Oct
15.	Sarson	*Brassica compestris*	Cruciferae	N+P	Dec-March
16.	Toria	*Brassica compestris var. toria*	-do-	N+P	Nov-Dec
17.	Shalgam	*Brassica rapa*	-do-	N+P	Feb-March
18	Mooli	*Raphanus sativus*	-do-	N+P	Feb-March
19.	Cucurbitacious vegetables	*Cucurbita spp*	Cucurbitaceae	N+P	Jun-Aug
20.	Jangali Jatoon	*Olea cuspidata*	Eleagnaceae	N	Feb-March
21.	Kaamal	*Mellotes phillipinensis*	Euphorbiaceae	P	Sept-Oct
22.	French bean	*Phaseolus vulgaris*	Fabaceae	N+P	July-Sept
23.	Makki	*Zea mays*	Graminae	P	July-Aug
24.	Phiunli	*Hypericum oblongifolium*	Hypercaceae	P	March-April
25.	White clover	*Trifolium ripens*	Leguminaceae	N+P	March-April
26.	Basuti	*Adhatoda vasica*	-do-	N+P	Mar-April
27.	Methi	*Trigonella foenum-graecum*	-do-	N+P	Feb-March
28.	Chhichhri	*Plectranthus rogosus*	Labiatae	N+P	Aug-Oct
29	Onion	*Allium cepa*	Liliaceae	N+P	Dec-Feb
30.	Harsingar	*Lagerstromia indica*	Lythraceae	N+P	July-Sept
31.	Dhain	*Woodfordia floribunda*	Lythraceae	N	March-May
32.	Tooni	*Toona ciliata*	Meliaceae	N	April-May
33.	Siris/Sarinh	*Albizzia spp.*	Mimosaceae	N+P	April-May
34.	Ohi	*Albizia lebbek*	Mimosaceae	N	May-June
35.	Babul	*Acacia nilotica*	-do-	P	July-Nov

36.	Khair	*Acacia catechu*	-do-	P	June-July
37.	Bottle brush	*Callistemon lenceolatus*	Myrtaceae	N+P	April-May
38.	Safeda	*Eucalyptus* spp.	-do-	N+P	Oct-March
39.	Jamun	*Syzygium cuminii*	-do-	N+P	May-June
40.	Amrood	*Psidium guajava*	-do-	N+P	Mar-April
41.	Poppy	*Papver dubium*	Papaveraceae	N+P	Feb-March
42.	Shisham	*Dalbergia sissoo*	Papilionaceae	N	Mar-April
43.	Robinia	*Robinia pseudoacacia*	-do-	N	April-May
44.	Buckwheat	*Fagopyrum esculentum*	Polygonaceae	N+P	Sept-Oct
45.	Darru	*Punica granatum*	Punicaceae	N+P	April-May
46.	Aroo	*Prunus persica*	Rosaceae	N+P	Feb-March
47.	Pazza	*Prunus puddum*	-do-	N+P	Feb-March
48.	Kainth	*Pyrus pashia*	-do-	N+P	Feb-March
49.	Plum	*Prunus domestica*	-do-	N+P	Feb-March
50.	Nakh/Pear	*Pyrus communis*	-do-	N+P	Mar-April
51.	Akhan	*Rubus ellipticus*	-do-	N+P	Mar-April
52.	Apple	*Mallus domestica*	-do-	N+P	Mar-April
53.	Gulabri	*Rosa* spp	-do-	N+P	Mar-April
54.	Loquat	*Eriobotrya japonica*	-do-	N	Feb-March
55.	Almond	*Prunus amygdalus*	-do-	N+P	Feb-March
56.	Apricot	*Prunus arminiaca*	-do-	N+P	Feb-March
57.	Malta	*Citrus cinensis*	Rutaceae	N+P	Feb-March
58.	Galgal	*Citrus limon*	-do-	N+P	Feb-March
59.	Lime	*Citrus aurentia*	-do-	N+P	Feb-March
60.	Sangtra	*Citrus reticulate*	-do-	N+P	Mar-April
61.	Gandhla	*Murraya koengii*	-do-	P	April-May

62.	Litchi	*Litchi chinensis*	Sapindanceae	N+P	April-May
63.	Soapnut	*Sapindus mucrosii*	-do-	N+P	May-June
64.	Beul	*Grewia optiva*	Tiliaceae	N	April-May
65.	Dhania	*Coriandrum sativum*	Umbelliferae	N+P	Feb-March
66.	Gajar	*Daucus carrota*	-do-	N+P	Mar-April
67.	Bunnah	*Vitex nigundo*	Verbenaceae	N+P	May-Oct
68.	Taur	*Bauhinia vahlii*	-do-	N	Mar-April
69.	Arjun	*Terminalia arjun*	Combretaceae	N+P	June-Sept

Bees as pollinators in Himalayan agro-ecosystems

Rapid deterioration of natural habitats due to construction/widening of roads, hydal projects in Himalayan rivers, deforestation, raising orchards in forest ecosystem, intensive monoculture, intensification of cropping systems, growing use of agrochemicals and chir pine (*Pinus roxburghii*) forest fires, etc. are the some of the reasons observed to cause decline in native honeybee populations. The honey bees are very small creatures, however, an important component of Himalayan farmer’s livelihood. They help in boosting crop yields in quantity and quality and reduce the cost of production by providing pollination services, sustain the managed vegetation along roadsides at various levels in rural and urban areas. Bee-pollination impacts seeding potential of each planted tree/shrub.

The traditional crop yields of buckwheat, amaranths, etc. have substantial declined because of reduced pollinators’ activities.

SRF for enhancing crop productivity

Pollination is an important and essential stage in the reproduction of flowering plants. The seed in almost all cultivated crops are needed for their multiplication and improvement. The short rotation forestry not only provides multiple benefits to the farmers but also support honey bee and other pollinating insects by providing shelter and their food. Whereas, not very few cultivated plants are totally dependent upon insects, quite a long list of crops and fruit trees can be drawn where insect pollination has resulted in more seeds of better quality. Induced honey bee pollination has resulted in 2.5 times more seed yield having 90 per cent germination potential (Chandel, et al., 2004). Singh and Chopra (1998) have reported that insect pollination has resulted in 387 per cent more fruit set in litchi (*Litchi chinensis*) fruit. Whereas, in citrus, 1.8 to 58 times more fruit set was observed in different citrus spp. (Singh and Garg, 1994) in outer Himalayan region. Demonstrations given at high Himalayan apple growing zones demonstrated that apple yield has increased up to 100 per cent (Sharma and Thakur, 2003).

Declining *Apis cerana indica* population

A study of 55 villages comprising tribal, tough terrained and non-tribal from north western Himalayan region, envisaged between 0-34 bee colonies/village during 2005-06, compared to 2-45, during 1995-96. During 1995-96, the maximum 37 numbers of *Apis cerana indica* colonies were recorded compared to 31 per village after one decade in village falling under inaccessible Tissa Block of Chamba District (between north latitude 32^{0}10’ and 33^{0} 13’ and east longitude 75^{0} 45’ and 77^{0} 33’). This reduction ranged from 9.1 to 100 per cent, during one decade. The study reveals that extensive agriculture/horticulture activities, rapid developmental activities mainly construction of hydel projects and roads has destroyed the undisturbed sites thereby reducing the hibernating and nesting place of the native pollinators.

Fodder for livestock

Agriculture and livestock constitutes the main occupation of over 90 per cent of population of mountainous state Himachal Pradesh, India. In the tribal region of the state, the livestock population is almost two and a half times more than the human population. The estimation of the value of livestock possessed by rural people can not be under estimated in formulating or estimating any of the economic indicators of rural people. Rural folks are dependent on a host of products and by-products produced through the exploitation of its cattle wealth both in fields in the form of bullock power required for cultivation, the application of manure to increase the production as well as the food requirements derived from milk and its by-products. It has been reported that about 25 per cent of the total animal diet of livestock is composed of fodder from trees and shrubs. Bamboo is foremost in biomass production, giving upto 40 tones per hectare in managed stands (Bhardwaj and Mishra, 2005). However, there is a wide gap in demand and supply of green fodder. It is estimated that about 64 per cent of green and about 24 per cent dry fodder will be deficit in the year 2015. To narrow down this gap covering wasteland and managing agriculture lands with fast growing trees is the utmost need. Introduction of these trees will ensure a higher yield of better quality fodder round the year and save the native forests from degradation.

SRF for soil health

Ameliorative effects of fast growing tree species have been reported from outer Himalayan agro-ecosystem. A decrease in soil pH by 0.4 units, bulk density (BD) by 0.1 mg m^{-3}, improvement in OM content by 0.16 per cent and water holding capacity by 1-5 per cent was observed in valleys of Uttarakhand State (Dadhwal and Tomer, 1999). In another study from Garhwal Himalaya, improvement in soil health was recorded overtime in minespoil degraded lands. After 14 years with agroforestry interventions, pH of minespoil decreased to 7.5 from 8.1, OC increased from 0.13 to 0.42 per cent, whereas, $CaCO_3$ content decreased from 54.6 to 31.0 per cent and BD from 1.63 to 1.47 mg m^{-3} (Dhadwal, 1999). These studies envisaged that planting of multipurpose trees help in improving the soil characteristics and crop productivity.

Multi-purpose trees interventions on water logged soils

The physical deterioration of soil due to waterlogging or flooding has affected around 11.6 million ha land in India. In Himalayan region, area occupying lower topographic positions adjoining to other non-hilly states and area along rivers are a few examples. These lands are generally not remunerative for crop production but offer an alternative to increase the production through silvopastural and hortipastural systems. Fast growing tree species i.e., *Casuarina* sp., *Eucalyptus* sp., *Syzygium* sp., *Acacia* spp., *Grevillea* sp., *Terminalia* spp., etc. have been recorded suitable for reclaiming such lands.

SRF for cold desert

About 10 million ha in the western Himalayan states of Jammu and Kashmir, Himachal Pradesh and Uttrakhand, lying between the Greater Himalaya and the mountains on the edge of the Tibetan plateau are a cold desert (Rani, 1999). This is an unstable and ecologically fragile region, situated in the towering mountain ranges and experiences extremes of cold and dryness. The ever increasing biotic pressure on this cold desert vegetation for fuel, fodder, household timber and grazing has led to serious ecological degradation. *Hippophae rhamnoides*, an important indigenous multipurpose shrub, N_2 fixing, of the region, is used as fuel, food and fodder by the local inhabitants of this region. One ha plantation of this shrub can meet the fuel wood demand of about 20 families (ICFRE, 1993). Some clones of eucalyptus, poplar and salix have been introduced as species for revegetation of cold desert in these areas.

Watershed management and ground water recharge

An integrated approach comprising mechanical, vegetative and agronomic measures is required for the successful and purposeful management of watershed programmes in Himalayan region. Tree species like *Acacia* spp. and *Prosopis* sp. planted in the lower Himalayan watershed not only provided cover to denuded hills and wastelands but also provided fodder, fuel, timber and staking wood for vegetable crops, thus helped in improving the socio-economic status of the people (Singh and Hazara, 1994). Growing of these fast growing species greatly helped in increased biomass production and rehabilitation/eco-restoration of degraded land through soil and water conservation. The suitable multipurpose tree performing better are *Albizia* spp., *Acacia* spp., *Butea monosperma, Leucaena leucocephala, Terminalia arjuna, Holoptelea integrifolia, Acrocarpus fraxinifolius, Morus alba, Eucalyptus* spp., etc.

Highways landscaping

Presently, construction of highways in the Himalayan tract and widening of existing road are the prioritized areas of the government. Thus, the first adverse consequence is inevitable felling of trees along roadsides project sites. Roads should not be looked upon merely as a means of transportation, but an integral part and parcel of the physical environment. Earlier, the first row of plantation used to be done by using tall shade bearing trees. With the development of high speed highways and widening of rural roads, the concept needs to be changed. Now, the first row along the highways should be of small to medium size fast growing trees and shrubs, thereafter, subsequent rows depending upon space should be of ornamental/shade bearing species of increasing height. Therefore, an intelligent selection of trees to be planted for roadside land scaping is of utmost importance to reduce impacts of air pollution, dust and sound pollution, providing shade, moderate effects of wind and incoming radiation, provide nesting places, shade, nectar and pollen to pollinators to support crop productivity of adjoining areas. Projects like Blooming Highway have been launched with the support of private investors to give a soothing effect to the road infrastructure.

SRF for enhancing human health

Domestication and cultivation of medicinal plants like neem (*Azadirachta indica*), amla (*Emblica officinalis*), harar (*Terminalia chebula*), bahera (*T. belerica*), bel (*Aegle marmelos*), mentha (*Mentha arvensis*), aloe (*Agave* sp.), tulsi (*Ocimum* spp.), imli (*Tamarindus indica*) and arjun (*Terminalia arjuna*) are the history old common practices of mountainous farmers. Cultivation of these medicinal plants in different agroforestry models have made tremendous effect in improving of human health and economic conditions of rural people. With the changing climate, the role of Himalayan ecosystem has increased to conserve the biological diversity. Vegetation shift has already been predicted upwards the elevation and few species are required to be introduced, tested, adopted and conserved to increase the biodiversity base in the Himalayan region for future generation.

Employment generation

There are large number of products for which we have to depend on forests either natural or man made. These include pole/bamboo and small timber for rural housing, timber for manufacturing, sawn wood and wood composites, hard woods for all types of paper and paper products, fodder and fire wood, non-timber forest products, plant extracts for medicines, etc. Bamboo has a tremendous potential to create jobs at the village level as well as at the industrial level. It has a capacity to provide employment and income to a fairly large number of people especially suited to women to allow flexible working hours near by their houses. Indian bamboo (6 million tones annually) sector generates 48-60 million work days for harvesting annually and 60-72 million work days for loading, unloading, handling, etc. (INBAR, 2001). Harvesting creates 8-10 work days to harvest one tone of bamboo, weaving to make baskets and trays takes 40 working days per ton thus, generating 120 million days of employment in the country as a whole. The craft sector can generate 150 work days per tone. In this sector, two tones of bamboo are enough to employ one person for one year (Rao, 1996). Bamboo also makes an ideal material for housing throughout Himalayan tract, which is prone to frequent earthquakes. The edible bamboo is used to prepare traditional dishes. Presently, 30 million trees of poplar, producing 1.125 million m^3 industrial wood annually are standing in various Himalayan states in combination with agricultural crops in various spatial patterns. It is estimated that around 25,000 ha equivalent plantation of poplar are now being established every year in association with a number of agricultural and horticultural crops under a rotation of 6-8 years. This has created much needed employment to many people not only in plantations activities but in industries (Chandra, 2001). An associated benefit of a native honey bee *Apis cerana indica* was found to provide an income of US $ 20-82 from a single colony kept in rural areas without any management interventions.

SRF for Himalayan region

In the foothills of north western and central Himalayan mountains poplar (*Populus deltoides*) plantations with a rotation of 6-10 years are raised by the farmers very commonly. In the north eastern region too, harvesting of poplar for pulping at rotation age of 4-6 years is recommended for obtaining optimum yield of biomass and pulp. High density short rotation mixed plantations comprising fast growing nitrogen fixing and non-nitrogen fixing tree species viz., *Leucaena leucocephala*, *Melia azedarach* and *Eucalyptus* hybrid in sub-tropical foot hills, whereas, *Robinia pseudoacacia*, *Acacia mollissima, Ulmus* spp*., Anus* spp*., Acrocarpus* sp*., salix* sp*., Morus* sp., etc. in the sub- temperate mid hills of north-western Himalaya have been found suitable for site amelioration and biomass production for fuel and fodder. North-eastern hill region of India possesses largest species diversity of bamboo. Outside the forest the bamboo is generally grown in shifting cultivation, as a component in agroforestry, homestead systems and wastelands. Bamboo is basically a household plant species around the houses and compounds (homestead), on farmland and other available places on farm holdings.

Constraints

The various studies conducted on the introduction of new species have established that the Himalayan farmers' livelihood sustenance will depend on increasing biomass production, soil amelioration and stabilization/rejuvenation of degraded lands, conserving biodiversity and protecting native important pollinators. However, such recommended farm models have not been adopted by farmers enthusiastically due to the lack of awareness about the short and long term benefits of short rotation forestry, location/need based specific agroforestry technologies, low interest in planting and management of tree species in their fields, long gestation period of the tree component, non-availability of quality planting material, inadequate financial support from government and financial institutions to grow trees and also a strong movement from non-governmental organizations against planting of fast growing species especially eucalyptus and poplar. The government's restriction on cutting, sale and inter-state movement of timber is also one of the major constraints for farmer's insensitivity towards adoption of trees on their farm.

Future thrust

a) Designing suitable location specific fast growing species based models for degraded, steep sloppy arable as well as non-arable lands. Demonstrate the attributes of the fast growing trees and their uses to the stakeholders
b) Both plants and pollinators live in symbiotic relationships, hence any planning towards one aspect needs to be looked at in relation to other.
c) Awareness of farmers, village and municipal representatives to understand the role of fast growing trees as service providers in their respective areas.
d) Development of silvi-pastoral models for augmenting tree fodder resources round the year.
e) Selection of trees with immense flowering potential blooming at different times in diversified landscapes
f) Development of crop, fruits, livestock and beekeeping based integrated farming system.

Conclusion

It is concluded that the well known favourable effects of short rotation forestry interventions are most beneficial to sustain the Himalayan mountainous farmers' livelihood options. These are beneficial in stabilization, amelioration and rejuvenation of sloppy degraded soils, meet multiple needs for food, fodder, fuel wood, fiber, fertilizer, sustain pollinator population and diversity and finally guarantee economic and environmental security for safe and protected habitat for humans and other living organisms. They have high potential of sequestering carbon, conservation of biodiversity, watershed protection and finally sustainable development of the highly fragile and tough terrain of Himalayan region.

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Full papers

High value utilization of wood from SRF-revised version in China

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1. Introduction

The status of forest and timber resources in China: The percentage of forest cover in China is 20.36% currently, globally ranking at 139 with only amount 2/3 of the average global value. The total area of forest is 195million hectares, the area of planted forest is 61,688,400 hectares, the volume of planted forest is 1.96 billion m^3, China ranking here first in the world. On the other hand the per capita value of forest area is only 0.145 hectares, less than 1/4 of world average; and the per capita of forest volume is only the 1/7 of the world's average.

The characteristic of forest resources in China: The distribution of resources is geographically uneven: the eastern region is covered by forest by 34.27%, the central region by 27.12%, the western region by 12.54%; the quality of forest is poor, the volume per hectare is only 84.37m^3, which is 84.86% of world's average, ranking China 84 of the world; unfavourable diameter and age-class distribution, the average diameter at breast height is only 13.8 cm, few resources available for harvesting.

2. The current situation and development tendency of timber in China

2.1 The distribution of forest resource in China

1) Greater Higgnan Mountains, Lesser Khingan Range and Changbai Mountain, the maximal natural forest in China;
2) Hengduan mountain area in southwest, the second largest natural forest;
3) Taiwan, Fujian, Jiangxi mountain area, mainly planted forest.

2.2 The development tendency of timber

China is a country consuming wood and wood products and with the development of society, the demand for wood products continues to grow. In 2009, total supply of wood products was 42,234.49 million m^3, this was an increase by 13.74% compared to 2008, of which imports amount to 18,436.62 million m^3 which is the equivalent of 43.65% of the total supply; the consumption of wood products was 42,189.48 million m^3 and rose by 13.58% compared to 2008, mainly for industrial and construction material, which consumption is 32,516.47 million m^3, amount of the 77.07% of total wood products consumption. (The last figure is the consumption of wood products especially for industrial and construction material.)

This shows that China's own production of wood products is not sufficient to meet the demand of timber, there is a tense relationship between supply and demand, China needs to rely on a large number of imports to fill the vacancy. Establishing a system for the efficient use of wood, increasing the rate of multipurpose utilization of wood, improving the implementation of SRF are efficient ways for high value utilization of wood. The comprehensive utilization rate of wood in China is only 65% (means the rate from logs to wood products) according to the statistical result from China Development and Reform Commission. The rapid development of timber industry in China in recent years was at the cost of consuming a large amount of wood, involved cheap labour and damaged the environment.

Table 1. Forecast on the demand for timber in main industry of China

No.	Industry	Consumption in 2005/m^3	Consumption in 2010/m^3	Consumption in 2020/m^3	Total consumption
1	Paper making	14,180,000	33,750,000	61,200,000	109,130,000
2	Wood panel	63,900,000	51,000,000	55,000,000	169,900,000
3	Wooden furniture	16,800,000	23,000,000	37,000,000	76,800,000
4	Architectural ornament	56,000,000	64,400,000	72,200,000	192,600,000
5	Packaging	8,000,000	12,000,000	18,000,000	38,000,000
6	Coal and Mining	3,000,000	3,000,000	3,300,000	9,300,000
7	Transportation	2,700,000	3,000,000	3,800,000	9,500,000
8	Chemical industry & stationery	2,300,000	2,800,000	3,600,000	8,700,000
9	Others	35,000,000	47,000,000	60,000,000	142,000,000
10	Total	201,880,000	239,950,000	314,100,000	755,930,000

2.3 The main utilization of SRF in China

Wood is one of the four major raw materials in the world, a traditional material, mainly used for paper making, panels, furniture, architectural ornament and packaging material. China is the second largest consumer of timber in the world, regarding the consumption of plywood, pulp paper and paperboard consumption it ranks second in the world, ranking third in the world regarding total wood consumption.

Take paper making for example, the tree species good for paper making should meet the requirement that it can be cultivated in short rotation, is easy to grow and has a high fiber content. Harvested wood includes bark, cambium and xylem. Bark has a negative effect on paper making, so it is necessary to remove it before it enters the pulping process. Whereas xylem is the main material for paper making: The higher its content within a tree species, the better for paper yield and quality. Also, there is a particular structure in some species, resin canals, which are detrimental because resin increases the required amount of chemicals during the paper making process, so species without resin canals are preferred.

Take a wood-based panel for another example, the main tree species for this utilization are *Poplar, Pinus massoniana, Birch, Eucalypt.* In total there are three types of wood-based panels: plywood, chipboard and fiberboard. Timber logs for plywood should have a stem diameter bigger than 20cm and the minimum log length should be 3 meters; the wood should show beautiful patterns, not easily warp or deform. Compared to wood from short rotation, the quality is more important. Whereas for chipboard and fiberboard, SRF is more suitable, because there is no special requirement for the raw material, even residues can be used.

3. The high value utilization of SRF in China

The characteristics of SRF result in that these kinds of trees are of poor quality with a small diameter, using them directly appears inefficient, so the value has be increased by additional enhancing measures such as:

1) A functional improvement of the wood surface via bleaching and dyeing, which can convert the color and texture of wood to enhance the appearance, and convert low quality to high quality resulting for instance in decorative wood veneer imitating valuable wood products.
2) Improve the physical and chemical properties of wood, such as antiseptic, antiflaming treatments, which can achieve that the timber may be used for particular areas with special properties, or producing wood-based composites like wood-plastic composites and wood-metal composites.
3) Make good use of the chemical component of wood to increase the efficient of timber using, which can be realized as hydrolysis, gasification, pyrolysis, plastify of wood

Take wood pyrolysis for example, the wood science and technology institute of Beijing Forestry University was founded in 2002 and mainly engaged in the research on the woody biomass material and energy utilization, especially on fast pyrolysis of biomass. Fast pyrolysis means fast heating rate (10^3°C/min-10^5°C/min), short residence time (<2s) and medium target temperature (about 500°C). In pyrolysis, biomass reacts in an anaerobic environment, even forest residues can be used as raw material. Products of pyrolysis are syngas, bio-oil and bio-char. Syngas can be used as heating source for several purposes, bio-char can be used as a semi-finished product to produce activated carbon, and bio-oil is an industrial raw material for many chemical products. It is one of the most important way to improve the efficiency of utilization of wood from SRF.

4. Utilization and development of Chinese poplar

4.1 The resource and distribution of Poplar in China

Poplar is one of the main plantation species in China, China has introduced poplar as the mainly reproducing tree species from America and Europe in 1951, the development of it included the afforestation of garden (which is used for beautifying the environment) - protection forest (which aims to protect and improve the ecological and environmental) – agroforestry - SRF, and has attracted worldwide attention on its introduction, breeding and cultivation. According to morphological characteristics of Populus, it can be divided into five main sections (or groups), namely: *Leuce*, *Tacamahaca*, *Aigeiros, Turanga , Leucoi*

Table 2. Species of poplar in China

Leuce	*Populus alba*
	P.alba var.pyramidalis
	P.tomentosa
	P.tomentosa var.borealo-sinennsis
	P.hopeiensis
	P.davidiana
Tacamahaca	*P.simonii*
	P.cathayana
	P.pseudo-simonii
	P.gansuensis
	P.yunnanensisi
	P.charbinensis
	P.xiaozhuancia

Aigeiros	*P.jrtyschensis*
	Populus X canadensis cv. 'Sacrou'
	Populus X canadensis cv. 'Robusta
Turanga	*P. Euphratica*
	Populus pruinosa Schrenk
Leucoides	*P.lasiocarpa*
	P.wilsonii
	P.heterophylla

The area of poplar planted forest in China is 7,572,300 hectares, accounting for 18.93% of the whole forest covered area, more than that in other countries in the world. Poplar is mainly distributed in the vast region between the latitudes of 20∞ to 53∞40 ' and longitudes from 76∞ to 140∞. Main area of distribution is as follows (the table appears with a light green background):

Table 3. The distribution of poplar in China

Southeast and Inner Mongolia forestry	Heilongjiang Liaoning Jilin Inner Mongolia Ningxia	*Populus davidiana, Populus euphratica, Populus pseudo-simonii, Populus charbinensis, Populus koreana, Populus maxuimowiczii, Populus hsinganica , Populus ussuriensis , Populus girinensis Skv. , Populus nakaii Skv.*,
Northwest forestry	Xinjiang Qinghai Gansu	*Populus euphratica, Populus alba, Populus canescens, Populus pamirica kom, P.bolleana*
North China forestry	Hebei Beijing Tianjin Shanxi Jiangsu Anhui Henan Shandong	*Pobulus davidiana, Populus hopeiensis Hu et Chow, P.cathayana, PopulussimoniiCarr.,*
loess plateau forestry	Shanxi Yanan Ningxia Gansu, lanzhou	*Populus pseudo-simonii, P.cathayana, Populus cathayana Rehd. var. latifolia C.Wang et Tung, Populus simonii Carr., Populus simonii*

4.2 The characteristics and application area of planted poplar

Poplar is adaptable, with a uniform and detailed texture, high survival rate, rapid growth and can be grown in short rotation. It is a soft-wood material with high fiber content and has a high tenacity and elasticity. All the characteristics result in being suited for the production of veneer, plywood, core-board and medium density fiberboard (MDF), especially for paper making and modern textile industry. But planted poplar has some weaknesses, like low density (average density is about $0.36g/cm^2$), a high uneven distribution moisture content, belong to stress wood, prone to shrinkage deformation and easy to peel during the process. In addition, due to improper cultivation methods, planted poplar is not regular in the form, one can find a black heart, many knots and worm channel.

When the trunk suffer the external force, in order to keep the trunk upright or horizontal position, the upper side and lower side of the cambium separatist activities will change, and cause the eccentric growth, one side of rapid growth will generate an exception the organizational structure, this wood is known as the stress wood.

This is a weakness that the stress wood has low intensity, and appears cottony phenomenon in the process, it is hard to be dry, easy to generate warping and craze.

4.2.1 For wood-based panel

Poplar is good for producing veneer because of its suitability for short rotation and its trunk shape. Timber from planted poplar has become the main raw material for wood-based panel industry in China. In laminated wood and core-board, poplar is used as the material for cross-band veneer. They are light and easy to process, can be widely used in furniture manufacturing and interior decoration. Small diameter logs, the part versus a branches' tip, the branch and processing residues are the ideal material for making chipboard and MDF with good appearance quality.

4.2.2 For paper making

Wood used as the material of paper making should be of short rotation type and meet the following requirements: light color, long fiber, small difference on wood fiber cell thickness between earlywood and latewood, high fiber content, low lignin, pentose, resin and ash content. Apart from shorter fiber length, other features of planted poplar are nearly the same with spruce: pure white color, little resin and easily to be bleached. Pulp yield, strength and whiteness can be taken into account at the same time during the process, so it is an appropriate material for paper making, can be widely used. All the residues from processing and the oriented cultivation poplar can be used as the raw material.

4.2.3 For artificial decorative veneer

Artificial decorative veneer is a kind of new veneer decorative material, using common tree species, especially planted poplar as raw material, via bleaching or dyeing with chemicals to imitate the color, patterns and various decorative patterns of valuable tree species. Varieties and specifications of the products are free to design and processing, and can ensure the consistent quality, which is conducive to large-scale industrial production, and can increase the additional value of the products, obtain significant social and economic benefits. Please what is to be understood by 'artificial decorative veneer'. Does this involve mixing poplar with chemicals? Please otherwise specify here if the veneer is obtained via rotary cutting because benwood project partner Peter Liebhard/Austria is going to publish an article on this for a project in Romania/Europe.

4.2.4 Modification of planted poplar

Modification of planted poplar is mainly to remedy that poplar is soft, has poor strength, high moisture, easily shrinks and is easily deformed, is fluffy when being peeled and has a poor dimensional stability. After the modification, the properties like dimensional stability, resistant to abrasion, non-corrosiveness, fire resistance, bend strength, surface hardness and modulus of elasticity are significant improved, which is very helpful for the utilization in particular areas.

4.2.5 For others

Timber from poplar is light, with uniform and straight grain, non-toxic, does not contain resin, so it can be used for building components (doors and windows, etc.), furniture, boxes, penholder, chopsticks, toothpicks, popsicle sticks, matchsticks, railway sleepers and so on. There are relevant standards indicating that poplar can be used as railway sleepers both in China and America; it is easier for anti-corrosion treatment of poplar than many other species, such as pine and red pine. In fact, using the poplar after antiseptic treatment as the railway sleepers is better than pine.

4.3 Development of poplar in China

The diameter of short rotation poplar can reach 25cm after 10 years, stress wood, prone to shrinkage deformation and easy to peel during the process, which has a bad effect on the wood processing and utilization. To improve the level of comprehensive utilization of poplar, on the one hand, we should orient poplar breeding according to the end-use requirements on wood, on the other hand, overcome the negative effects resulting from the processing and utilization. Specific solution approaches are as follows:

1. Improve the physical and mechanical properties of wood

2. Focus on the improvement of genes and oriented cultivation, select the fast growing species of high quality, achieve this goal via forest-engineering integration.

3. Improve the techniques of enhancing and conditioning wood, like drying, antiseptic, modification, antiflaming coatings, etc.

4. Produce a high-valued composite board, high yield pulp and paper products, develop new species used for decoration and construction.

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Contract pulpwood farming – methods and impacts in supply chain

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Introduction

Contract farming is an effective and efficient system of success for production and consumption systems of agricultural and allied sectors. It is an essentially agreement between unequal parties, which include the growers, processors and consumers (Eaton, 1998: Gahukar, 2007). Contract farming is viewed as essentially benefiting the promoters or user agencies by enabling them to obtain the necessary raw material on sustainable basis (Gupta, 2002). In the era of market liberalization, globalization and expanding agribusiness, there is a danger that small scale farmers will find difficulty in participating in the market economy (Jackson and Cheater, 1994). In many cases, small farmers could become marginalized as larger farms become increasingly necessary for profitable operations. This system of contractual farming existed from time immemorial but the success in many sectors of agricultural production is of recent origin.

In contrast to agriculture, the production in forestry is of long rotation in nature. Besides, the forests of the country are under acute socio-economic pressure and till recently, the deforestation rate in the country was estimated to be 1.5 million ha $year^{-1}$. Currently the forest area in the country is around 23.57 per cent and Tamil Nadu state is around 17.41per cent (FSI, 2005), which is low against the mandated requirement of 33 per cent. The less forest area coupled with low productivity of Indian forest has ushered in a large gap between demand and supply of both domestic and industrial wood requirements (Parthiban and Govinda Rao, 2007).

The biggest challenge faced by wood based industries is the raw material shortage. A conservative forest policy coupled with promotion of farmers/ industries linked plantation activities on under-utilized cultivable and marginal agricultural lands will help to mitigate the crisis. This necessitates a business farm forestry model, in order to expand the area under farm and agro forestry plantations through multi-stake holder's participation. A multi functional agroforestry systems in India has already been elaborately indicated (Pandey, 2007)

The success of industrial wood plantation schemes and the related plantation establishment is widely questioned. The reasons for the failure are numerous; but the key reasons are non-involvement of local people, lack of quality planting stock, lack of assured buy back / minimal support price etc. The middlemen and local contractors in the existing marketing system play a significant role and in most of the cases, they decide the harvesting time and also price fixation. Absence of efficient production to consumption system coupled with price incentives and assured buy back agreement is a major constraint faced by the tree growing farmers. This constraint on industrial agroforestry can be overcome through augmenting the existing supply chain system by linking the farmers directly with industries through contract farming system. The success of WIMCO seedling Ltd. for popular in North-Western states and ITC for clonal eucalyptus are the resultant initiatives of mult-istakeholder's partnership on quality planting stock, marketing, finances, etc. (Pande and Pandey, 2004; Dhiman, 2008; Karmarkar and Haque, 2008). Hence the quad – partite model contract farming system through public private partnership has been introduced in the state of Tamil Nadu involving various levels of stake holders and its success is discussed in this manuscript.

Pulp wood industries

There are about 600 paper mills in India and about 39 paper industries in the state of Tamil Nadu and in which two industries are wood based and the remaining industries are based on agricultural waste or other sources of fibre. The two industries viz., Tamil Nadu News Prints and Papers Limited (TNPL), Karur and Seshasayee Paper and Boards (SPB), Erode use predominantly hardwoods like Eucalyptus and Casuarina as a raw material. These two paper industries required nearly 4.0 lakh tonnes of wood pulp and most of the raw material requirement is met from the Forest Department and partly from farm lands. Currently, both the industries have expanded their paper production capacity, which ultimately resulted in the wood pulp demand of nearly 8.0 lakh tonnes per annum against the actual availability of around 3.5 to 4.0 lakh tonnes of wood pulp. Industries have developed contract farming system through technological support from Forest College and Research Institute of TNAU at Mettupalayam, Tamil Nadu.

Existing supply chain

Currently there existed multipartite supply chain system as indicated in the Fig.1. The major raw material supply comes from the Forest Department which accounts for nearly 1.5 lakh tonnes of wood pulp supply (TNPL, 2008). The remaining raw material comes from other sources viz., farmer, exporters of pulp and wood both within and outside India as indicated below.

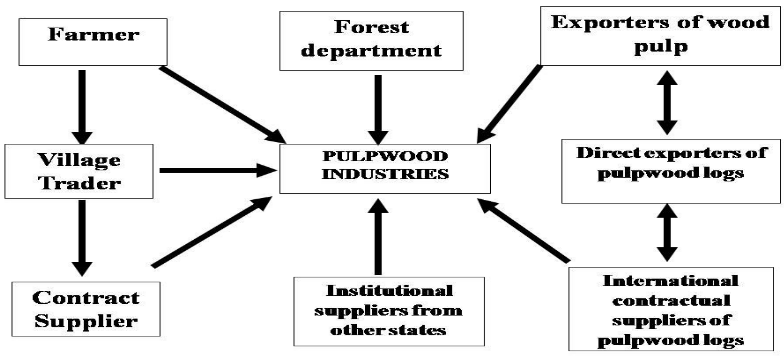

Fig.1: Multipartite supply chain system

Multipartite pulpwood supply chain

The second major supply of pulpwood is from farm holdings. However the farm grown pulpwood is not coming directly to the industry. In the existing supply chain, growers sell the whole plantation on the acreage basis not taking into consideration the actual volume of the growing stock, which resulted in minimal returns to the growers. The local contractor's buy the plantations, fell them and classify them into poles, pulpwood and firewood. Only the wood size of 1 to 2 inches alone is supplied to the industries and other sizes are sold for pole purpose by the traders, which resulted in uncertain and erratic pulp recovery and quality (SPB, 2008). This necessitated development of strong supply chain with a successful contract farming model.

Contract farming models

To meet the above needs and increase the area under pulp wood plantation through farm forestry, the two paper industries in association with Tamil Nadu Agricultural University has developed a tripartite and quad-partite models for promotion of pulp wood based contract farming system. Through the system, it is intended to produce quality and sustained raw material through a strong supply chain.

a. Tri-partite model

This model incorporates industry, growers and financial institutions. Under this system, the industry supplies quality planting material at subsidized rate and assures minimum support price of € 314 per tonne or the prevailing market price which ever is higher. The financial institutions viz., Indian Bank, State Bank of India and Syndicate Bank provide credit facilities to the growers at the rate of € 235 to € 314 per acre in three installments. For credit facilities, a simple interest rate at 8. 5 per cent is followed and the repayment starts after felling. The contract farming system extends no collateral security for loan amount up to € 1570 per farmer.

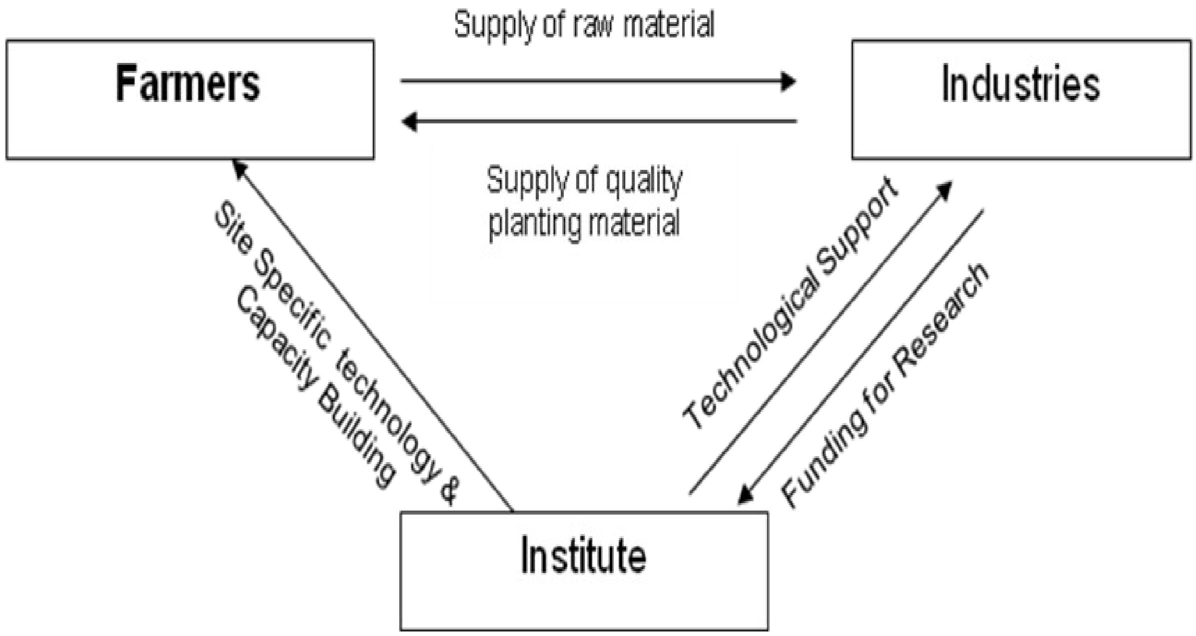

Fig. 2: Tri-partite Model contract tree farming

b. Quad-partite model

This system is similar to tri-partite model barring the involvement of research institute (Fig. 1). In this system, research institute particularly Forest College and Research Institute (TNAU) play a significant role for technological advancements through varietal development and also to advice site specific silvicultural technology to the growers. A pre and post-plantation scientific advice helps to develop human resources through on and off institute mode to farmers and plantation staff of the industries.

Similarly, the industries mass multiply the potential genetic materials identified by the research institute in a decentralized manner and supply them at subsidized costs. The industry also facilitates felling and transport at their own costs, which resulted in strong linkage between industry and the farmers. The industry also help to repay the loan amount after felling of farm grown raw materials there by help the financial institutions for timely repayment, which resulted in strong institutional mechanism for sustainability of the contract tree farming system in the state. Hooda and Hooda (2005) emphasized to provide suitable packages to provide credit facility and marketing to recap benefits of agroforestry/ farm forestry to reduce poverty in rural areas.

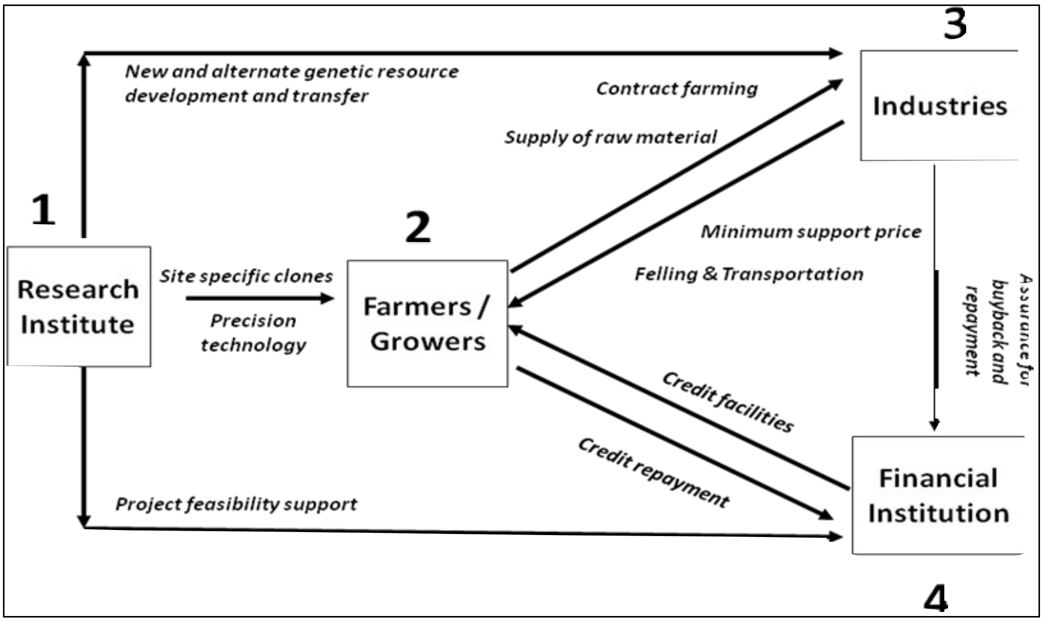

Fig. 3: Quad-Partite Model contract tree farming

Technological support

Forest College and Research Institute, TNAU, Mettupalayam has established research linkages with both the pulp wood industries in order to develop high yielding short rotation varieties along with needed site specific silvicultural technology for augmenting productivity and to address the site specific problems. Accordingly, short rotation clones in *Casuarina* species have been developed, which could be harvested in 36 months with an average yield of around 100 tonnes/hectare and maximum yield of 150 tonnes/hectare. Similarly, high yielding clones in *Eucalyptus tereticornis, E. camaldulensis, E. europhylla* and their inter-specific hybrids have been developed. These elite planting materials coupled with silviculture technologies have been successfully transferred to farm land condition with industrial participation through a contract farming system developed and promoted by the institution.

Contract farming methods

The contract farming in the State of Tamil Nadu, India is promoted through the following three approaches.

a. Farm forestry method

In this method, the industry supply the quality planting materials of site specific variety identified by the research institute to the interested farmers on a subsidized rate. The farmers in turn develop his own plantation and obtain the needed technological support from the research institute. If needed the farmers get credit facility from the financial institutions and final felling and transportation by the concerned paper industry. An agreement is made before the plantation establishment. In this method, the farmers grow only trees without any intercrop and mostly practiced in dry land condition.

b. Agroforestry method

The farmers raise pulpwood plantation as a major crop and grow suitable intercrops and this method is practised mostly in garden land conditions. The other conditions are similar to that of Farm Forestry Method.

c. Captive method

In this method, the industries intend to develop their own plantation through land lease or benefit share model. The large land holders and the lands available with government and private sector which were unutilized for a longer period are utilized. A minimum land size requirement of 10 hectare for 1 cluster unit is needed. Once the land is identified the land holder can opt either land lease model or benefit share model.

d. Land lease model

In this method, the land owner and the industry will have an agreement for lease amount and the lease period. As per the existing lease agreement, € 16 per annum for dry lands and € 47 per annum for garden lands are practised. Once the lease agreement is signed, the industry will establish their captive plantation and the period of lease is for one rotation and tenable further based on mutual consultations.

e. Benefit share model

Under this method, the land owner agree to share the benefits at the time of harvest. Accordingly, an agreement is made wherein the industry will establish the plantation at its own cost and the benefit will be shared at 70 (industry):30 (land owner) for dry lands and 60 (industry) : 40 (land owner) for garden lands. The benefit share is worked at the total yield of the produce.

Planting material

Currently pulpable species viz., *Casuarina, Eucalyptus*, *Leucaena*, *Melia dubia* and various Bamboo species are promoted in the state. However, the farmers in the state mostly prefer Eucalyptus for dry lands and *Casuarina* under irrigated conditions. In both the species, superior genetic resources both through progenies and clones have been developed for commercial adoption.

Both the pulp wood industries have developed centralized facilities for mass multiplication of *Casuarina* and *Eucalyptus* through clonal approaches using rooting of coppice shoot cuttings (*Eucalyptus)* and through sprigs (*Casuarina*). The clonal technology developed by Tamil Nadu Agricultural University for mass multiplication of *Casuarina* and *Eucalyptus* has been transferred to industry for large scale adoption and multiplication. The clonal planting materials are supplied to all stake holders at subsidized rates through contract farming system.

Pulp wood plantations covered under contract farming

In order to have better monitoring and improve working efficiency with minimum logistic expenses, contract tree farming activities were confined initially to a compact area i.e., around 200 km from the mill site but as on date the entire state of Tamil Nadu is covered except hill districts. During the last three years the contract pulpwood farming promoted across the state has gained significant momentum which resulted in more farmers attracted towards contract tree farming as indicated in the increase in area over years. (Table. 1)

Table 1. District wise status of contract pulp wood farming in Tamil Nadu

S. No	District	2008-2009		2009-2010		2010-2011		2008-2011	
		SPB	TNPL	SPB	TNPL	SPB	TNPL	Total (Acre)	Total (Ha)
1	Ariyalur	813	1689.4	218	2065.54	0	2215.09	7001.03	2800.412
2	Chennai	15	0	10	0	10	0	35	14
3	Coimbatore	14	0	3	0	2	0	19	7.6

4	Cuddalore	51	0	64	0	4681	0	4796	1918.4
5	Erode	148	0	107	0	18	0	273	109.2
6	Karur	4	438.77	0	262.1	0	662.29	1367.16	546.864
7	Kancheepur am	0	0	186	0	0	0	186	74.4
8	Krishnagiri	0	0	6	0	1	0	7	2.8
9	Nagapattina m	13	0	0	0	0	0	13	5.2
10	Namakkal	189	150.36	89	199.07	3	393.05	1023.48	409.392
11	Perambalur	2	0	2	0	0	0	4	1.6
12	Pondicherry	10	0	82	0	0	0	92	36.8
13	Pudukottai	433	1514.07	275	1117.28	0	3776.06	7115.41	2846.164
14	Salem	52	0	88	0	3	0	143	57.2
15	Sivagangai	2	277.78	0	434.46	0	1109.97	1824.21	729.684
16	Tanjore	190	787.65	41	834.62	0	1053.68	2906.95	1162.78
17	Trichy	129	1844.52	20	1191.04	1	681.87	3867.43	1546.972
18	Tiruvanamal ai	58	0	134	0	1	0	193	77.2
19	Tiruvarur	93	0	29	0	0	0	122	48.8
20	Tiruvallur	0	0	48	0	0	0	48	19.2
21	Vellore	0	0	18	0	0	0	18	7.2
22	Villupuram	133	2476	292	2982.17	3	4635.94	10522.11	4208.844
23	Virudhunaga r	11	0	0	0	0	0	11	4.4
24	Tirunelveli	0	183.64		109.35	0	850.5	1143.49	457.396
	Total	**2360**	**9362.19**	**1712**	**9195.63**	**4723.00**	**15378.45**	**42731.27**	**17092.51**

As on date, two industries have concentrated in 24 Districts of the state and covered nearly 42731 acres (17092 ha) under the contract tree farming system (Table.1 and Fig. 4) Among two industries, TNPL, a state government owned industry has established more area (13574 ha) under contract farming than SPB (3518 ha) . Among the districts Villupuram district recorded maximum area under contract farming (4208 ha) due to the acceptance of the model coupled with the presence of traditional coastal tree growers. These coastal tree growers were periodically shifted towards clone based pulpwood farming due to technological support from the research institute. This was followed by Pudukottai district (2846 ha) and Ariyalur district (2800 ha). These two districts are traditionally dry districts and huge extent of unutilized marginal lands were converted into successful pulpwood plantations.

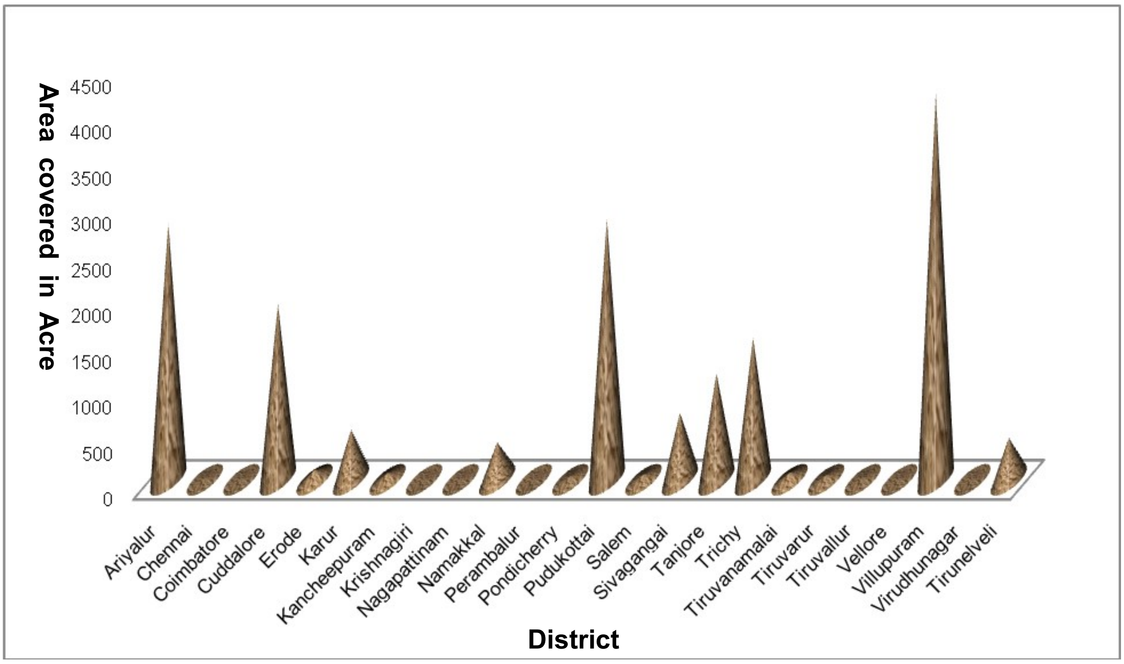

Fig. 4: Status of contract pulpwood farming in Tamil Nadu

The pulp wood based contract farming system established by the two pulp wood industries in the state indicated that farmers in Trichy, Pudukkottai, Sivagangai and Karur districts are more interested for pulpwood plantations preferably with Eucalyptus plantations. In these districts, *Eucalyptus* was preferred under rainfed conditions. However, the farmers in Cuddalore, Tanjore, Villupuram, Vellore, Nagapattinam and Thiruvarur districts preferred *Casuarina* based pulpwood plantations due to higher returns from the tree coupled with traditional acceptability of *Casuarina* in the coastal regions.

Impacts of the pulpwood contract farming

The introduction and implementation of contract pulpwood farming has created significant impact in terms of supply chain, income and employment generation coupled with environmental benefits.

Organized supply chain

This contract farming model has converted multipartite pulp wood supply chain into Bi-partite supply chain wherein the farmers supply the material directly to the industries as per the pre-plantation agreement. This resulted in maximum benefit to the tree grower because the farmers sell the product on quantity basis against acreage basis before introduction of the system. The industries in turn benefited through assured supply of raw material along with quality products.

Income and employment generation

It is estimated that 300 man days are required for establishment of one ha of plantation from seedling up to harvesting and transportation. These flow of operations have created 5.1 million mandays of employment for an area of 17092 hectare covered under contract farming. This employment potential has resulted in income generation to the tune of € 471 per hectare and € 8.05 million for 17092 hecatre and the benefit is distributed to various stake holders viz., farmers, landless labourers and members of women self help groups.

Carbon sequestration and climate mitigation

The sub-project has excellent scope of mitigating the climate change through carbon sequestration. It is estimated that an average of 50 tonnes of carbon is sequestered in one ha of plantation. The current plantation established in this sub-project has the potential of sequestering 0.85 million tonnes of carbon yielding revenue of € 2.5 million. This carbon sequestration potential may help to augment the environment and may result in clean development mechanism for the globe in general and the region in particular. The plantation growers will also be benefited through carbon credit mechanism for which the lead institute is taking enough efforts to develop the operational methodology.

Conclusion

Contract farming through public private partnership has long-term benefits for both the grower and the purchaser, provided that their long-term association is mutually complementary. Contract farming, as it existed then was different from the design and functioning of contract farming method today. Tree farming is gaining momentum in the state through the institute-industry linked peoples' participation. The pulp wood industries in the state of Tamil Nadu promoted pulpwood based contract farming system and contributed significantly for the successful establishment of *Eucalyptus* and *Casuarina* based pulp wood plantations. The industries have adopted tri and quad-partite contract farming models and these systems proved successful in promotion of farm forestry across the state. In the tree based contract farming system, industry provided quality planting material in terms of seedlings and clones coupled with strong buy back system. Besides, the contract farming system also facilitated availability of credit facilities, which attracted more number of small farmers entering into pulp wood plantations. This contract farming system has proved lucrative in the state, which resulted in successful industrial agro and farm forestry model for pulp and paper industries.

Acknowledgement

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Value addition of agroforestry plantation residues through briquetting technology for energy purpose

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Introduction

The energy consumption in the country is steadily increasing over years but there is no concomitant increase in biomass availability. In India, about 46% of the total energy consumption is estimated to be met from various biomass residues viz., agriculture residues, animal dung, forest waste, fire wood etc (Ravindranath and Hall, 1995). The major portion of the agriculture residues produced in the country is used for domestic utility (Tripathi et al. 1998) and the direct burning of agriculture residues in domestic as well as industrial application is very inefficient due to wide range of biomass sizes and varying water content coupled with more ash content. Moreover transportation, storage and handling and other logistic issues also create problems in their sustainable utilization. Hence forests in general and the forest biomass in particular played significant role in energy generation due to their sustainable availability and the associated positive factors like low ash content and increases burning efficiency coupled with their role in environmental amelioration. This created the scope of large scale demonstration and establishment of energy plantations in the country thereby helped to resolve the issues on energy unavailability. These forest biomass were utilized directly both for domestic and industrial consumption which resulted in inefficient energy conversion coupled with the associated environmental issues due to the smoke and the ash that emanated from direct burning of forest residues. This besides the huge volume of biomass residues (other than the major woody biomass) viz., twigs, branches, leaves, saw dust, bark etc., have been so far under or unutilized for want of suitable conversion technology and the associated operation and logistic issues. To resolve these issues, the major approach widely practiced in the country was briquetting or densification technology; however, such technology was not practiced for converting the forestry plantation residues into briquettes. Hence the current study was conducted and successfully evidenced the conversion of plantation residue based value addition through briquetting technology for deployment in energy utility to meet the growing energy demands of the country.

Significance of wood based biomass energy

Wood fuel plays an important role in the economy of rural people. It provides local income and employment. About 70% of the rural population in India is dependent on wood energy. It is also used by the medium and metropolitan group to meet their day today energy needs. In India, wood fuel contributes to the extent of 69.2% of the rural energy needs and 35.5% of the urban sector. The consumption of wood fuel is estimated to be around 300 million tons per annum. Wood fuel is more sustainable than fossil based fuels like coal, peat, oil or bituminous rock. No doubt the combustion of wood emits Co_2, but the reforestation or regrowth of these forests capture it back. The use of cogeneration technology has made a carbon neutral. Hence the wood as direct energy and wood converted into various fuel forms have contributed significantly the energy needs of the country and requires enough attention for their promotion, popularization and rationale utilization to have clean environment.

Biomass residues availability for briquetting

Essentially the residues from agriculture sector, forest biomass, saw dust from timber mill can be successfully briquetted. The agriculture residues which do not host collection and drying problem are also suitable for briquetting but not as a direct raw material but as a blended material. The suitability of raw material for briquette production rely on several factors but the prominent characteristics are moisture content, ash content, flow characteristics and particle size. Moisture content is preferred in the range between 10 and 15 and the ash content up to 4%. The particle size of the raw material must be uniform and the preferred size ranged between 6 and 8 mm which provide uniform flow in screw conveyors which facilitate easy briquetting and avoid blockage. In India, wide range of raw materials viz., saw dust, groundnut shell, cotton stalks, maize stalks, rice husk, tamarind shell. Coir pith, coffee husk, mustard stalk, sunflower stalk, baggasse, wood chips etc., are used either singly or in combinations. The raw material suitable for briquetting is classified into three categories viz., fine granulated, coarse granulated and stalky biomass. However, the use of Casuarina residues has not been evidenced or reported anywhere in the country and hence the current study formed a pioneering attempt which proved lucrative in terms of income and employment generation.

Constraints

The major constraints faced by the briquetting industries in the country are:

- The spectare of raw material unavailability
- Sporadic availability of raw material
- Wide variation in biomass
- Availability of higher volume of raw material with uncertain quality
- Seasonal availability
- Collection, transportation and other logistics
- Higher moisture content
- Availability of soil and other inert materials in the agriculture biomass
- Unorganized marketing and trade resulting in poor supply chain

Scope of briquetting

The constraints listed above are not exhaustive but only indicative which thus extent adequate scope for briquetting in order to create self reliance in energy sector through value addition process. The briquetting technology will help to convert the diverse biomass into a value added quality products thereby create considerable scope for establishment of value addition industries in rural and urban centers. These establishments will help to create adequate income and employment generation activities thereby help to auger the socio economic status of the rural dwellers. Above all, white smoke coupled with low ash content in the briquettes will create clean and sustainable environment and help to achieve the policy requirements of the country.

Briquetting enterprise and the processing technology

a) Machineries

Briquette production is recognized as a business enterprise which predominantly uses wood residues. Most of the briquetting units in the state of Tamil Nadu, India utilizes around 70% of wood based saw dust and 30% of agro residues for all types of briquette production. The briquetting enterprise will require the following machineries viz., cutting, pulverizing machine or hammer mill grinder, drier, briquetting press. The schematic diagram of a briquetting plant setup at the host institute is depicted in Fig. 1.

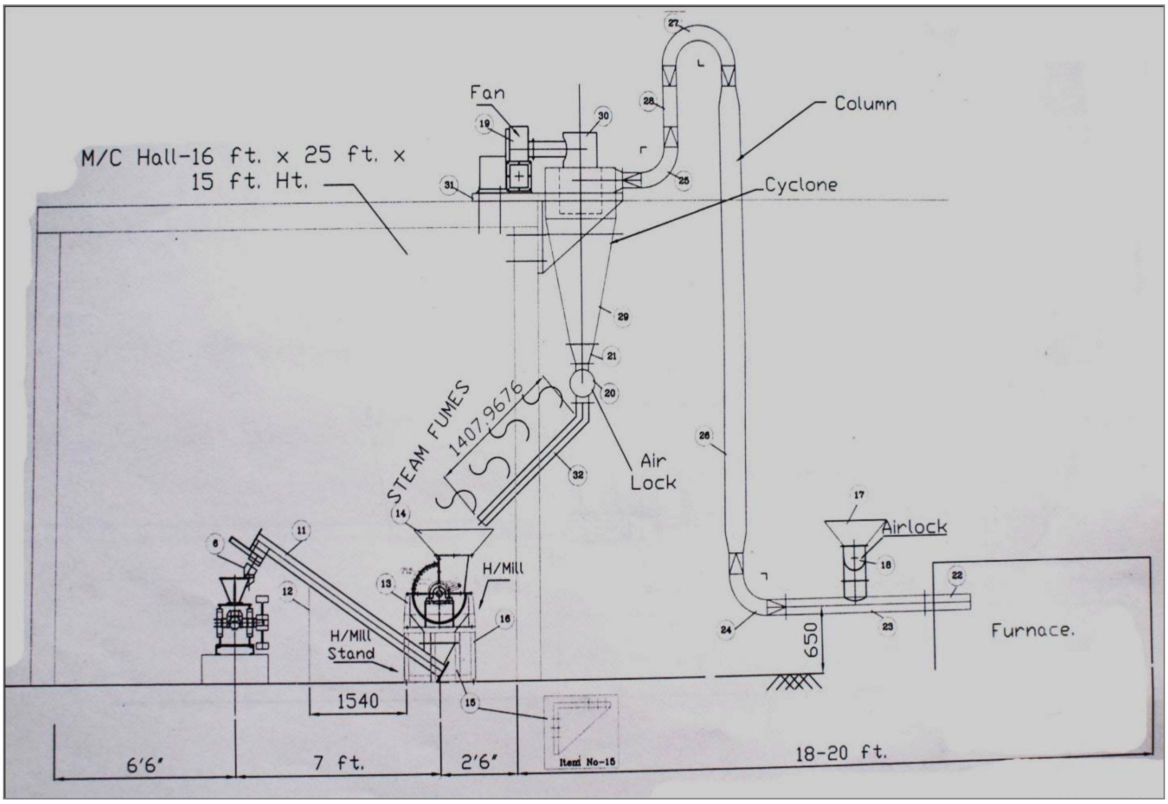

Fig. 1: Schematic Diagram of Briquetting Plant

b) Processing technology

The briquetting process involved are drying (reduction in moisture content), size reduction (change in surface area to volume ratio) and densification (change in density).

c) Drying

It is a method of removing moisture content of biomass. The heat generation of biomass is dependent on the moisture content, therefore drying of biomass is essential for enhancing its calorific value. It has been observed that only about 9% of energy value of biomass are lost in reducing the moisture content from 30 to 9%. But if it is not reduced the decrease in calorific value is about 26%. The optimum moisture content of the raw material suitable for briquetting is between 7 and 10% (Hasan Yumak et al. 2010).

d) Size reduction

Size reduction of biomass is done to convert it to a convenient transportable, storable and usable form. These processes include tree cutting (removing stems and branches from tree), log cutting to convenient size for use and log cutting to small billet form for use.

e) Densification

This process is to increase the bulk density of biomass for efficient and convenient transportation and handling. It also reduces the requirement of bulk storage space. The physical dimensions and the combustion characteristics of the fuel become homogeneous and uniform due to the availability of required particle size, porosity and density which result in efficient energy conversion.

The densification processes are broadly three types:

1. **Binderless densification technique**
   In this method, no external binders are added for compacting the material however the process is done at high temperature (85 – 105^oC) and at high pressure (1500 kg / cm^2).

2. **Densification with binders**
   In this method, the pressure requirement is low but the binding materials such as tar, molasses, resins, wax, or other biological binding materials like tamarind and cashew shell are used along with the biomass to enhance densification process.

3. **Pyrolysis**
   In this method, the biomass is first carbonized and the charcoal obtained is powdered and then compacted in required size and shape.

The flow of industrial process involved in briquetting technology is depicted below in the Fig. 2.

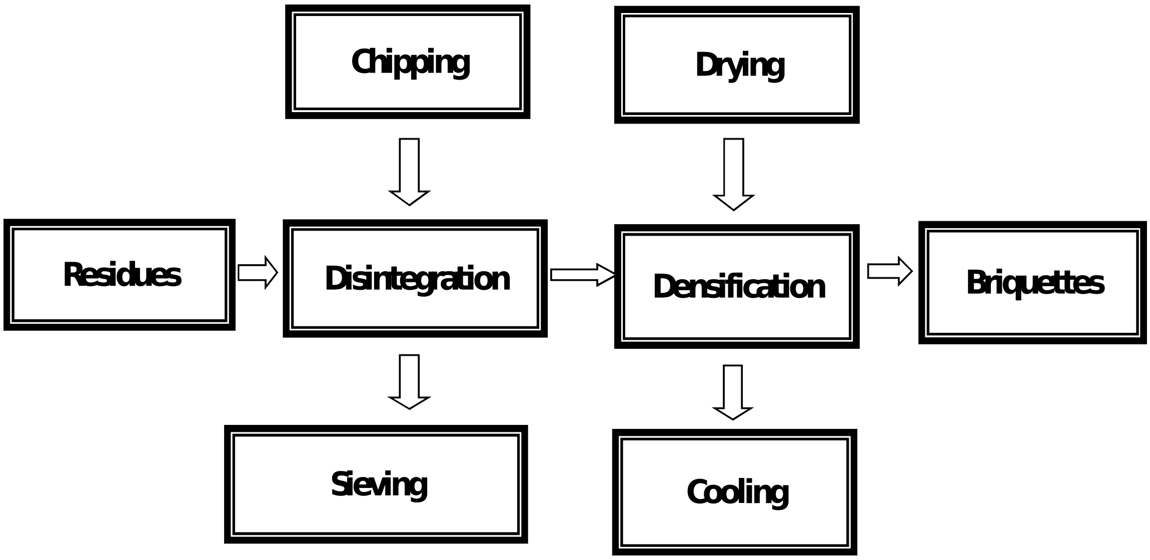

Fig. 2: Briquetting process

Thermo-chemical analysis of briquettes parameters

The current study on Casuarina needles, Eucalyptus plantation residues, Jaropha (TBO) fruit husk, match wood residues and plantation residues of Melia dubia were successfully converted into briquettes and the thermo-chemical study findings are furnished in Table 1.

Table 1. Briquetting quality of various tree residues

Sl. No	Raw materials	Volatile matter %	Ash content %	Heating value MJ.kg-1 (DB)	MC %	Calorific value K.cal/kg
1	Casuarina needles	15.53	7.77	31.54	5.06	4950
2	Eucalyptus plantation residues	12.87	3.96	32.87	7.42	4426
3	Jatropha (TBO) fruit husk	17.82	9.90	30.78	4.15	2968
4	Matchwood industrial	14.42	4.81	32.56	4.48	4714

	residues					
5	*Melia dubia* plantation residues	15.00	8.00	31.46	5.01	3650

Economics of briquetting

The economics of briquette production using various dominant raw materials were assessed. The fixed cost consisted of Rental value of building, Machinery items- depreciation and Electricity deposit and the variable cost comprises of Raw material cost, Transport cost, Labour charges, power consumption, Spares, Lubricating oil, Packing, Miscellaneous cost and Interest on working capital. The economics of briquette production revealed that Casuarina residue based briquette production resulted in maximum net revenue of INR 1763.00 per ton of briquette produced and thus lend support for further promotion of Casuarina needle based briquette production.

Table 2. Economics of briquette production using different tree based raw material (Euros / ton)

Particulars	Saw dust	Casuarina needles	Mill Residues	TBO Residu es
Variable cost				
Raw material cost	17.27	12.56	23.55	14.13
Transport cost	3.14	3.14	3.14	3.14
Labour @ of two women and one man labour / ton	4.71	4.71	4.71	4.71
Power (Electricity) (Rs. 4.25/ W)	3.14	3.14	3.14	3.14
Spares	1.18	1.18	1.18	1.18
Lubricating oil	0.79	0.79	0.79	0.79
Packing	3.14	3.14	3.14	3.14
Miscellaneous	0.79	0.79	0.79	0.79
Interest on working capital (14%)	4.79	4.13	5.67	4.13
Total variable cost	38.94	33.57	46.10	35.14
Fixed cost				
Rental value of building (operating & store room)	1.57	1.57	1.57	1.57
Machinery items- depreciation	1.33	1.33	1.33	1.33
Electricity (power connection)	0.24	0.24	0.24	0.24
Total fixed cost	**3.14**	**3.14**	**3.14**	**3.14**
Total cost	**42.08**	**36.71**	**49.24**	**36.71**
Selling price	**64.37**	**64.37**	**64.37**	**64.37**
Net price	**22.31**	**27.68**	**15.15**	**26.11**

Utility and other benefits

The forest biomass based briquette production technology has significant utility and made tremendous impact in terms of value addition of underutilized biomass (nearly 5 to 8 tonnes of green biomass) into value added briquettes thereby help to create adequate socio economic and environmental impact. The state of Tamil Nadu, India is currently housed with nearly 0.1 million ha Casurina plantation which will result in the availability of 0.5 to 0.8 million tones of green biomass distributed in 24 districts of the state. Hence establishment of decentralized value addition units may result in efficient utilization of biomass residues and their conversion into briquettes will result in meeting the energy requirements of the country.

Benefits of the briquetting

- Utilized as domestic and industrial fuel for energy supply
- The bulk density is increased from 80-200 kg/m^3 to 600-800 kg/m^3
- The specific density will range from 1,100 – 1,200 kg/m^3
- Increased heating efficiency
- It produces white smoke and low ash and hence environmentally safe fuel

Conclusion

The art of briquetting technology attempted using various forest biomass residues proved quite attractive in terms of technological value coupled with the associated economical and environmental values. Though all forest residues are amenable for briquette production, the superiority of Casuarina needle based briquette production proved efficient in terms of calorific value, combustion efficiency and bulk density. Above all the availability of 0.1 million ha plantations of Casuarina in the state of Tamil Nadu have attracted many to venture into the Casuarina needle based briquetting technology. It is expected that with the increase in cost of fossil fuels, depleting reserves of natural forests, the net zero carbon emitting biomass briquettes may find large scale application in industrial and commercial applications besides satisfying the energy demands of domestic needs. Above all the efficient value addition process will help to augment the logistic issues and will create clean development mechanism through white smoke and low ash from the briquettes. Hence it is ideal to establish one briquetting unit for every 200 ha of Casuarina plantation in a decentralized manner which will create self reliance in energy needs of the country.

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Resource potential and developing prospect of forest bioenergy in China

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1. Introduction

Energy consumption and environmental pollution have become a common problem that limits the global economic development. This is mainly caused by the limited fossil resources and the increasing demand for energy, leading to higher costs for energy consumption. In China, with the rapid economic development, the use of primary energy has led to a rapid growth since the 1990s. It covers a relatively high GDP (Gross Domestic Product) growth rate, over 8% annually. However, the energy consumption also increased greatly during the corresponding time. The consumption of standard coal increased from 1.30 billion tons in 2000 to 2.23 billion tons in 2005 with an average annual growth rate of 9.03%. The increasing energy consumption was strongly connected with an increase in greenhouse gas (GHG) emissions and thus, serious environmental pollution occurred during that period. The average annual rate of GHG emissions growth was around 4% from 1994 to 2004. And it is evaluated to be 1.28 billion tone of carbon in 2005 (Wei 2007). Therefore, consequently it is necessary to develop renewable energy with low emissions in China.

Forest bioenergy is considered as a popular substitute for fossil fuels to offset GHG emissions. It is produced with raw materials from special energy woods harvesting, residues of forest felling, shrub coppicing, sawmill and oil plants. Their final product can be divided into five types: biodiesel oil, bio-ethanol, woody solid fuel, woody gas fuel and woody power generation. A variety of advantages of forest bioenergy have been widely recognized in the past few years. It plays a positive role regarding the environment, reducing carbon dioxide emission and contributes to socio-economic aspects, such as gross domestic product (GDP) growth, employment creation and tax revenues increase (IEA 2009, Kumar et al. 2008, Gan and Smith 2006, Zeng and Gu 2005 and Domac et al. 2005).Wood harvesting for bioenergy can be reasonable and effective measure of promoting forestry training, speeding the forestation and preventing the land degradation (Smeets and Faaij 2007, Richardson et al. 2002). Utilization of forest bioenergy can improve the “carbon sink” function of the forest, considered as the typical case for “zero emission” of GHG emissions.

Forest biomass use for bioenergy increased particularly where wood processing residues are readily available, as in Finland and Sweden. However, in China, forest bioenergy is still in the early stage and several small-scale projects have just been set up. Great importance has been attended to such projects recently by the Chinese government promoting a number of new initiatives and incentive policies. Nevertheless, there is still uncertainty around the forest biomass evaluation and supply for bioenergy as well as production and utilization of bioenergy in China.

Therefore the purpose of this study is to evaluate the resource potential for forest bioenergy as well as to introduce the status of forest bioenergy and reveal current constraints of the industrialization in China. The obtained results may help to understand the development of commercial bioenergy from forest biomass and contribute to the further discussion regarding the potential of forest bioenergy industry in China.

2. Distribution and features of forest biomass resource for bioenergy in China

The resource 'forest' is widely distributed in China, with great variety of forest species. There are abundant areas of natural forest and plantation. Results of the recent national forest resources inventory (2004-2008) have shown that the forest area is 195.45 million hm2, forest coverage is 20.36%, alive stumpage cumulation is 14.913 billion m3 and forest cumulation is13.721 billion m3. Current estimates of the forest biomass are more than 18 billion tons with an annual net growth around 0.6 billion tons. There are about 900 million tons of forest branches and woody wastes available each year in China of which around 297 million tons can be used for bioenergy (NDRCC 2007, Lv et al. 2005). In addition, it is abundant in the resources of wasteland, deserted mountain and bare sandy land suitable for bush forest, around 54 million hectares (Zhang and Lv 2008). Traditionally, forest residues are widely used in rural areas of China for cooking and heating fuel or are fired directly causing severe environmental pollution. It is also rich in workforce resource with low workforce cost in most countryside of China, which makes it possible for collecting forest biomass and replanting for energy.

Resource potential of oil plants for biodiesel is enormous. There are six large families of oil plants, in which 197 species are with more than 20% of oil content. Suitable land for oil plants cultivation is sufficient. Currently, over 36 million hm2 of deserted mountain and sandy land is suitable for oil plants and over 20 species of oil plants are applicable for biodiesel production in China. To be specific, 2 million tons of seeds are produced in more than 4.2 million hm2 of oil plants area, of which, more than 900,000 tons are available for biodiesel production and the amount of biodiesel can be 300,000 tons annually in China.

Table 1. Types and quantities of woody biomass for bio-energy in China

Woody biomass types	Available harvesting area（Million hm^2）	Available woody biomass technically（Billion ton per year）	Available woody biomass for energy（Billion ton per year)
Branches residues from forest production	142.79	0.153	0.04
Energy forest	3.03	0.048	0.03
Shrub coppicing	45.30	0.15	0.05
Branches residues from forest thinning	91.00	0.239	0.05
Branches residues from economic forest	21.40	0.15	0.03
Branches residues from harvesting of bamboo forest	4.84	0.05	0.01
Branches residues from trees outside forests		0.03	0.01
Branches residues from urban green trees pruning		0.04	0.02
Residues from nursery stock pruning		0.015	0.01
Discarded wood-based products		0.08	0.04
Fruits or seeds from oil plants	4.2	0.002	0.001
Total		**0.957**	**0.298**

Artificial planting of certain oil plants is emerging in China. Several demonstration projects have shown that production of oil plants can be promoted greatly by selecting top-quality seeds and intensive management. At present, the most10 promising and valuable oil plants species for bioenergy include *Xanthoceras sorbif olia*, *Jatrapha curcas, Sapium sebiferum, Ldesia polycarpa*, *Pistacia chinensis, Rhus succedanea, Aleurites fordii* and *Cornus wilsoniana*. Table 2 shows the main oil plants species and their distribution in China. All mentioned oil plants are rich in oil content (Table 3) and can easily be growed in China due to available and suitable land. As experience about artificial planting is already available, high yields can be expected if the plantation and management is performed according to best practices.

Table 2. Main oil plants species and distributions

Species	Area ($1000hm^2$)	Harvest Yield (1000 ton)	Oil-content (seed) (%)	Distributions
Xanthoceras sorbif olia	10		35-45	Inner Mongolia, Shanxi
Jatrapha curcas	45	5	35-45	Sichuan, Yunan, Guizhou and Hainan
Sapium sebiferum	410	185	35	Guizhou, Hubei, Sichuan and Zhejiang
Ldesia polycarpa	30	10	28	Shaanxi, Guangdong, Guangxi, Hubei, Hunan, Guizhou, Yunnan and Sichuan
Pistacia chinensis	300	80	30-46	Middle China: Shaanxi, Hebei, Gansu, Shandong, Henan
Rhus succedanea	220	80	35	Middle China: Shaanxi, Guizhou, Hebei, Henan and Anhui
Aleurites fordii	1060	560	35-40	Guizhou, Hunan, Shaanxi and South China
Cornus wilsoniana	4		20	The Yangtze River Valley and Southwest China

Table 3. Yield of some oil plants species in China

Oil plants species	Oil content (%)	Seed yield (kg/hm2)	Initial stage (a)	Duration (a)
Aleurites fordii	49.4-58.6	3000-6000	3-4	10-20
Sapium sebiferum	22.8-41.6	2250-4500	3-8	20-50
Jatrapha curcas	50.2-61.5	3000-6000	3-5	30-50
Pistacia chinensis	25.6-52.6	1500-4500	5-8	50-100
Xanthoceras sorbif olia	55-67	1500-4500	2-3	30-80
Cornus wilsoniana	33-36	3000-6000	3-5	50-100

3. Development of forest bioenergy in China

The increasing utilization of bioenergy from the forest has resulted in a rapid development of associated conversion technology. Since 1970s, development of forest biomass energy has achieved notable success globally and showed an industrialization trend. Some developed countries, led by USA, Canada and some European countries, have become quite advanced in forest resources harvesting, energy conversion technologies and industrial development of forest bioenergy (van Belle et al., 2003, Bjornstad, 2005; Yoshioka et al., 2006; Rentizelas et al., 2009 ; van Dyken et al., 2010). The application of bioenergy in China is still in the early stage. However, steady progress is being made and several small-scale projects have recently been set up and gained wide awareness. It is very important for China to develop its forest bioenergy industry by learning from the experiences of the more experienced countries.

3.1 Woody solid fuel

At present, woody biomass for solid fuel is still in the developing stage in China. Most of producing factories are distributed in the forest-resource-rich regions. Production in China started in 1990s, with relatively low capacity of equipment and a high production cost. Up to 2000, the number of small and medium enterprises carried on the production was more than 40, and the domestic producing machines in running with capacity of 100~200 kg/h was more than 800. At present, capacity of main equipments used in China has been improved and reached one to three ton per hour. More and more technology institutions or companies started to engage in the research and production field of biomass solid fuel in China recently. For example, Jiangsu Liyang Machine Factory, Henan Energy Research Institution and Central South University of Forestry and Technology do research on the equipment for biomass pellets production, whereas a research group from Beijing Forestry University is dealing with research on the technology of wood biomass blocky-shaped fuel.

There are two kinds of woody biomass solid fuels involved in China, woody biomass pellets and woody biomass blocky-shaped fuel. Both are mainly used as fuel for industry boiler and hotel heating with a large price gap in different regions. A certain amount is also exported to North America, Europe and other countries of Asia. The purchase price varies in different regions as the forest biomass supply cost, from 150 Yuan/ton to 400 yuan/ton. If developed technology and equipment, for example ETS (EcoTre System) developed by Italy, can be introduced in China, processing costs will decline, accordingly (Chen et al., 2005).

Thus far, the output of the fuel is still very limited and just few official records on production and trading volume are available. Relevant production standard and pricing system are not established, yet. The main limitations for the development of biomass solid fuels in China are not only the high production cost and purchasing power but also the available stove-technologies. Traditional stoves are designed for burning coal and can’t be used for biomass solid fuels.

3.2 Power generation from forest bioenergy

Bioenergy power generation is a highly efficient way to use forest biomass. Especially high developed countries in North America and Europe made continuous and steady progress over the last decades (Yoshioka et al., 2006; Kumar et al., 2008). In China, progress is being made due to the establishment of several small-scale projects under the relevant policy support (Table 4) (Zhang, 2010). China’s central government predicts its power-generating capacity using agricultural and forest bioenergy will be around 24 GW in 2020 (NDRCC, 2007). In July 2010, China’s government introduced a feed-in tariff for electricity from agricultural and forest bioenergy. The on-grid price for electricity produced out of agricultural and forest bioenergy was raised to 0.75 Yuan per KWh, while the average price of electricity from fossil fuels was 0.355 Yuan per KWh (NDRCC, 2010). With this recent increase, power plants based on forest biomass may become feasible.

Table 4. Forest bio-power factories of China

Projects Name	Project progress	Investment (billion Yuan RMB)	Capacity (MW)	Types of fuel
Tongliao Naimanqi Forest Bio-power Factory	Trial operation	0.267	24	Forest residues
Maowusu Biomass CHP Factory	In operation	0.241	24	Forest residues
Arxan Forest Bio-power Factory	Feasibility research		24	Forest residues
Jiangxi Boyang Kaidi Bio-power Factory	Trial operation	0.25	24	Forest and agricultural residues
Anhui Chao Bio-power Factory	Feasibility research	0.272	30	Forest and agricultural residues
Shandong Guoneng Danxian Bio-power Factory	In operation	0.3	24	Forest and agricultural residues
Guoneng Afandi Bio-power Factory	In operation	0.29	24	Forest and agricultural residues

*Data collected in June 2007

The principal constraints of forest bio-power generation are high costs and undeveloped supply logistics of forest biomass (Ma, 2006; Jiang, 2007). This study examines the supply logistics for two locations in Inner Mongolia: Naimanqi which has a power plant supplied by a collectively owned forest and Arxan, with a proposing power plant supplied by a state-owned forest. The study areas differ in supply logistics and management structure due to the differences in collection process, equipment and hauling distance. It provides insight into the analysis of bioenergy feedstock from forests in northern China.

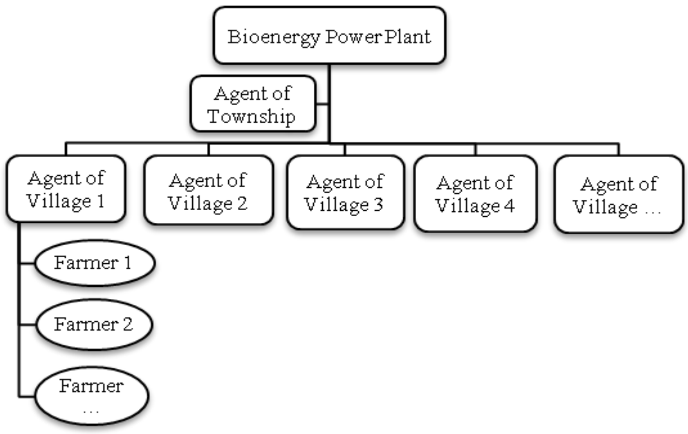

Fig. 1: Organisation of woody fuel supply in Naimanqi

In Naimanqi, the woody fuel for power generation is collected from a collective forest of ninety-six villages in the twelve townships1. The forest is contracted out by tenure to local farmers in small plots of 0.5 to 2 ha. A total of twelve township agents and ninety-six village agents arrange the woody fuel collection. Figure 1 summarizes the organisation of the power plant and the agents at the collection sites. The power plant signs contracts with the individual agents. The village agents organise the collection activity, while the township agents supervise the village agents in their respective townships.

The whole supply processing of wood fibre can be divided into skidding in the forest, hauling from the forest to village collection sites, delivery and storage at collection sites, transportation from the collection sites to the power plant, and inspection and chipping in the power plant (Fig. 3).

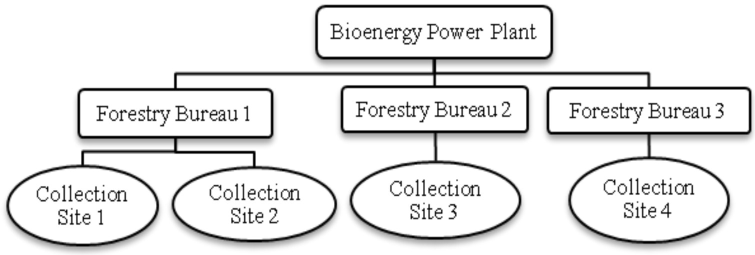

Fig. 2: Organisation of the woody fuel supply in Arxan

The organisation logistics of Arxan were developed by the Forestry Bureaus, who are the woody fuel suppliers of the proposed power generation plant. As shown in Figure 2, the proposed power plant will contract with the four neighbouring Forestry Bureaus within a 50 km radius. There are four recommended collection sites for collecting, chipping and storing the wood fibre (MCC, 2007). In Arxan, the supply chain is more complex due to the forest characteristics and climate conditions. Harvesting is only carried out in winter because of wet, soft soils during the rest of the year. Snow depth in the forest is around 50 cm making biomass collection more time consuming. The collection activities from the forest land to the collection site would be carried out in three steps and by three separate work groups, as shown in Figure 3. Chipping and storage are carried out at the collection sites. Then the chipped material would be transported by truck to the planned power plant.

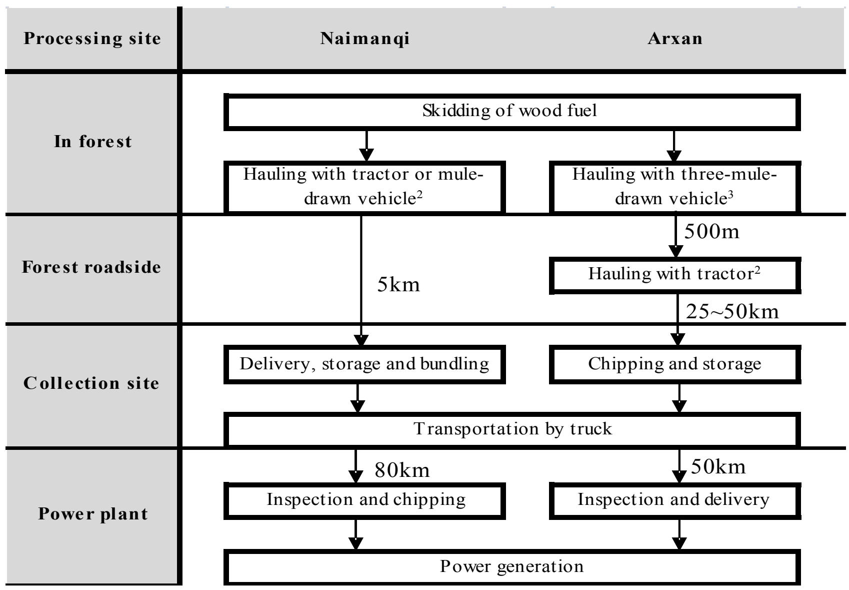

Fig. 3: Wood fibre supply chains in Naimanqi and Arxan1

* 1: Adapted from Yoshioka et al. 2006.; 2: Farm equipment with trailer; 3: Forestry equipment used in areas with heavy snow.

Biodiesel from oil plants

The present biodiesel production from oil plants in China is still in its infancy with driblet processing, backward technology and low production capacity. The process was promoted by several private enterprises providing the resource material like animal fat and vegetable oil. Up to now, there are just a few industrialized enterprises or projects due to the poor production technology and economic efficiency. The conversion technology from agricultural oil crops to biodiesel, however, has been well developed in many countries of the world, which can be introduced to China in the near future.

As to the raw material selection for biodiesel production, though some vegetable oils have been planted in large scale, such as colza oil, cottonseed oil and soybean oil, it is difficult to be used as the main material for biodiesel for their high prices. Some oil plants with rich oil content, e.g. J*atropha curcas*, *Xanthoceras sorbif olia* and *Pistacia chinensis*, have been considered as a promising material resources in China. However, as they are still in a developing phase regarding cultivation these plants can not act as the main raw material supply for biodiesel production, yet.

Recently, the Chinese government has vigorously promoted planting *Jatropha curcas*, which is expected to be one of the important oil plants for biodiesel production in China. Therefore, Sichuan province, Yunnan province and Hainan province were selected as the best representative regions for artificial planting of the oil plant. Several pilot projects were developed/established/founded for *Jatropha curcas* planting and biodiesel processing in Hainan province. In this study, detailed practical investigation was undertaken in some of the representative projects.
At present, two operating models of biodiesel production from *Jatropha curcas* exist in Hainan province. One is developed by private enterprises whereas the other one is controlled by state-owned enterprises.

Figure 4 demonstrates the operating model of a private company, BIO-ENERGY & CHEMICAL Company (BEC), in details. The Research, Development and Cultivation base, as an important research department, was established in order to provide seedlings and technology for *Jatropha curcas* planting. After harvesting abundant amounts of the *Jatropha curcas* oil, biodiesel was produced by the BEC. In addition, parts of seedlings from The Research, Development and Cultivation Base are also exported to the other countries such as Thailand, Malaysia.

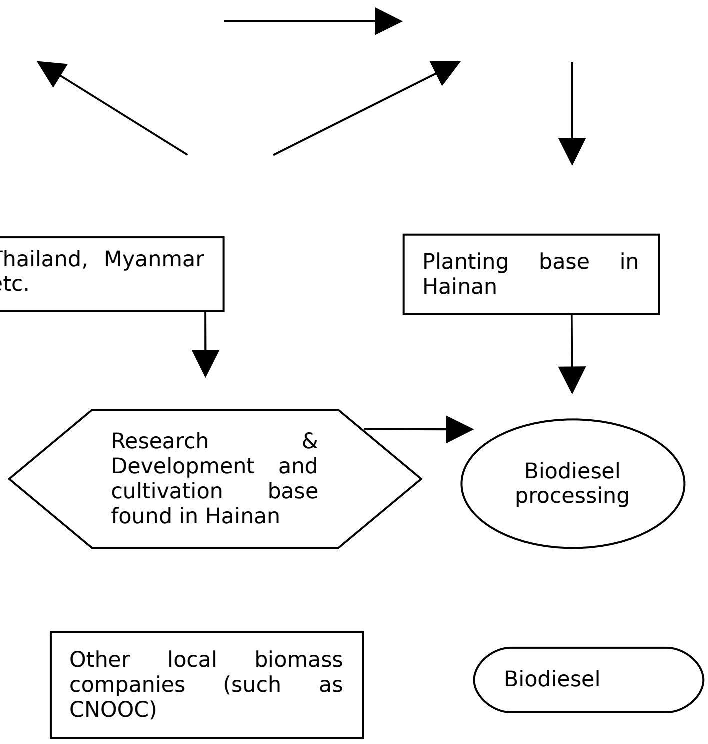

Fig. 4: Operating model of biodiesel production from *Jatropha curcas* by private company, BIO-ENERGY & CHEMICAL Company in Hainan province

The other model is managed by the State-owned enterprises ("CNOOC") in Hainan (Figure 5). The production chain was built by the company. Currently the company also established supply bases of seedlings, including cultivation and plantation of oil-bearing plants. The final product will be applied in the need of the local transportation.

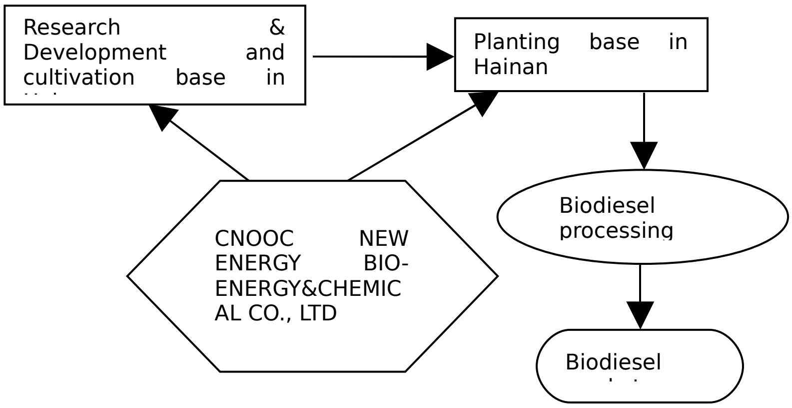

Fig. 5: Operating model of biodiesel production from *Jatropha curcas* by state-owned company, CNOOC Company in Hainan province

4. Results and conclusions

The relevant studies have shown that it is about time to develop forest bioenergy in China. However, the industrialization and development of forest bioenergy was limited due to behindhand feedstock, immature forest fuel market and high cost of forest biomass supply. Existing survey results on forest resource for bioenergy are not enough detailed and therefore the lack of knowledge makes it difficult government as well as for private companies to work out certain strategies in order to obtain major progress in this field.

Lacking of information, communication and capital investment in technology research, some key technologies and devices will depend on import for years. In addition, environmental benefits from forest bioenergy production and use cannot be reflected by the market because a professional evaluation system has not been established, yet.

The current government developed few specific strategies for forest bioenergy and few detailed implementation schemes. Though some policies have been involved they are not effective in promoting the development and still lack of incentive mechanisms. Most of forest bioenergy projects depend on governmental support or international grants, at least for the initial stage.

Therefore, it is necessary to take measures to promote the forest bioenergy in China. Firstly, assessment of forest biomass resource, availed for bioenergy using, is important. Based on the distribution of regional forest resource and bioenergy development planning, sponsors of the projects or plans need to do researches and then provide the detailed and reliable data in order to formulate forest biomass supply plan.

Secondly, the technical research mainly includes two sections for the forest bioenergy. One is for the forest biomass harvesting and supply chain, starting from tree species screening and planting, harvesting, transportation, delivery and treating procedures; the other one is on the technical path to improve production level contributing to industrialization of forest bioenergy, such as study on the key equipment, operation standard, as well as the market mechanism.

Finally, the government's support policies are needed at the initial stage of industrialization of forest bioenergy. Thus, public awareness about using forest biomass for bioenergy could be improved the related legislative systems and definite targets established by the government can support the development of forest bioenergy in the long run. For example, economic compensation and trade mechanism of bio-power can encourage the grid electricity sales and achieve the optimization of the forest resource deployment.

Acknowledgement

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Brazilian agroforestry systems

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Introduction

According to Somarriba (1992), agroforestry systems are a form of multiple cropping under which three fundamental conditions are met, there are at least two plant species that interact biologically, one of the plant species is a woody perennial and the other is managed for forage, annual or perennial crop production.

Brazil holds potential for implementation of many agroforestry systems models, being propitious to the consortia cultivation between short rotation forest and many annual crops. This potential can be evidenced by the fact that Brazil holds five distinct biomes, each one with high biodiversity, the country has a wide territorial extension of 8,514,876.599 km2, more than fifteen kinds of soil, around histosols, latosol, ultisol and sandy soils, and shows favorable climate conditions for planting of many vegetable species (IBGE, 2011).

Due to biological, climate and soil diversity and the potential uses of the forest resource, many agroforestry systems configurations can be found in Brazil. The Brazilian agroforestry systems aim at allying the diversity of cultivations, yield and soil conservation, once these systems promote better soil covering, favoring the fauna and flora preservation, promoting the nutrients cycling from the action of different root systems, and provide continuous fixation of the organic matter (Maia et al., 2006). Furthermore, greater diversity of products that may be harvested assures continuous income to the farmer, avoiding the seasonality of production, common in the Brazilian agricultural sector.

One of the agroforestry systems most broadcasted in Brazil is the interaction between crops, livestock and forest, and this integration model is called agrosilvipasture (FAO, 1989). Following the agrosilvipasture system, one of the configurations practiced in Brazil is the planting of annual crops during the first two years of the *Eucalyptus spp.* plantation. In the third year of the forest culture, a forage crop (*Brachiaria spp.*) is planted and from the fourth year on the cattle, aiming at fattening, enters in the system until the harvest of the trees (Salles, 2010).

Pereira et al. (1996) showed in technical document of Embrapa (Brazilian agricultural research company) that many arrangements of agroforestry systems have as forest component the rubber tree. The authors found rubber tree in agroforestry consortia with cocoa (*Theobroma cacao L.*); coffee (*Coffea arabica L.*); palms that aim the production of Juçara heart of palm (*Euterpe edulis*), Açaí fruit (*Euterpe oleracea*) or Peach palm (*Bactris gasipaes*); citrus species; and guarana (*Paullinia cupana* var. *sorbilis* Mart.).

In agroforestry systems aimed at family farming a variety of crops and tree species can be observed. Armando et al. (2002) showed that it is possible to integrate a high diversity of multiple uses species in an agroforestry system to family farming. This study used forest species with high density wood for luxury furniture, Mahogany (*Swiethenia macrophylla*) and *Copaifera langsdorffii*; biopesticide species that the seed oil is used to produce insect repellent and as raw materials for cosmetics, *Azadirachta indica* and *Carapa guianensis*; short rotation fruit species used food for households and for marketing, pineapple (*Ananas comosus*) and papaya (*Carica papaya*); medium rotation fruit species, *Euterpe* *oleracea*, Banana (*Musa cavendish*, *M. paradisiaca*), *Bactris gasipaes* and Coffee (*Coffea arabica*); and annual agricultural crops, cassava (*Manihot esculenta*) and corn (*Zea mays*).

Agrosilvipasture system

One of the agroforestry systems most broadcasted by the Brazilian forest sector is the consortia around annual crops, cattle for fattening and Eucalyptus spp., also named as agrosilvipasture system.

Salles (2010), studied the yield of *Eucalyptus spp*. in agrosilvipasture system. In this work that was made in “Aço Florestal” unit of the “Votorantim” group, the plantation of Eucalyptus spp., aims the wood production for energy and sawnwood, was made in spacing for trees of 10 x 4 meters and respect one meter spacing between the forest culture and the crops.

In the first year it was implemented the consortia between *Eucalyptus spp*. and rice, because rice presents less nutritional requirement. The soybean was planted in the second year with density of 200,000 plants per hectare, being the culture harvest waste incorporated to the soil. In the third year it was implemented *Brachiaria spp.* manipulated for fattening beef cattle. In the fourth year began the fattening beef cattle. From the sixth year, began the biannual buying and selling of the cattle until the harvest of the trees in the twelfth year (Salles, 2010) (Fig. 1).

Fig. 1: (A) *Eucalyptus spp.* and rice in first year of the Agrosilvipasture system of the Votorantim group, Paracatu city, Minas Gerais state, Brazil. (B) *Eucalyptus spp.* and soybean plantation in the second year. (C) Cattle fattening and *Eucalyptus spp.* plantation after the fourth year. Adapted of Salles (2010).

The yield of *Eucalyptus spp.* plantation for the best clone in the best site was, approximately, 170 m3.hectare-1 in the seventh year. To the worst clone in the worst site the yield was, approximately, 100 m3.hectare-1 in the seventh year.

Pinus spp. agroforestry systems

A type of agroforestry system which uses *Pinus spp.* cultivation is the agrosilvipasture, following the same configuration adopted by the *Eucalyptus spp.* culture, described above. In the two first years annual crops were planted, in the third year the pasture was planted and for the fourth year the area was free for fattening beef cattle. However the rotation for *Pinus spp.* cultivation is between 20 and 25 years, aiming at the production of sawnwood, laminate and wood chips. Flores et al. (2010), in Rio Grande do Sul state, showed a variation of this system with lines of *Pinus spp*. and *Eucalyptus spp.* in the forest component, and in the fourth year it was used sheep flocks as the animal component (Fig.2).

Fig. 2: Pinus spp. in consortia with flock of sheep in Rio Grande do Sul state, Brazil. Photograph of Flores et al. (2010).

Medrado et al. (2005) showed an agroforestry system composed of *Pinus spp*. x Yerba mate (*Ilex paraguaiensis* St. Hilare) x Soybean. In this system the *Pinus spp.* was planted in spacing of 10 x 4 meters; the Yerba mate in spacing of 4.5 x 1.5 meters; and the Soybean was planted between planting rows of Yerba mate cultivation (Fig. 3).

Fig. 3: Pinus spp. in consortia with Yerba mate (*Ilex paraguaiensis* St. Hilare) and Soybean in Rio Grande do Sul state, Brazil. Photograph of Adroaldo José Waczuk cited by Medrado et al. (2005).

Comparing the utilization of *Pinus elliottii* or *Eucalyptus grandis* in agrosilvipasture systems, Oliveira et al. (2008) showed in his results that the *E. grandis* culture presented carbon proportion in relation to wood volume higher than *P. elliottii* culture, mainly due to the higher basic density of *E. grandis* wood (Table 1).

Table 1. Volume, carbon and CO2 equivalent per hectare, age 21 for *Pinus elliottii* and *Eucalyptus grandis* showed by Oliveira et al. (2008).

Plantation density (trees/ha)	***Pinus Elliottii***				***Eucalyptus grandis***			
	Volume (m^3/ha)	**Volume (m^3/tree)**	**Carbon (Mg/ha)**	**CO_2eq. (Mg/ha)**	**Volume (m^3/ha)**	**Volume (m^3/tree)**	**Carbon (Mg/ha)**	**CO_2eq. (Mg/ha)**
500	283.3	1.13	63.1	231.6	256.2	1.71	71.5	262.4
1,000	315.1	1.05	70.6	259.1	291.3	1.46	80.2	294.3
1,111	375.9	0.76	84.1	308.7	359.0	1.20	98.8	362.6

Agroforestry systems of family farming

The agroforestry systems turned to family farming in Brazil are multi-stratified, being composed of more than one forest species and many annual and perennial crops. By this way, farmers have financial incomes in short term with the annual crops, in medium term with the perennial crops and in long term with the forest species. The higher diversification of the plantation reduces the risk of market seasonality and provides more liquidity for the productive unit due to the diversity of the products obtained.

According to Armando et al. (2002), the union of different cultures in the same productive system requires the design of the spatial distribution of plants and their time evolution. The same authors showed that the biodiverse system planning must take into account the needs of light, the size, the shape of the root system of each species and its behavior in the climate and soil type of the region.

Armando et al. (2002) showed a model of agroforestry system configuration turned to family farming, developed by Embrapa that gathers 36 species and is opened to public visitation in 'Vitrine de Tecnologias da Embrapa', Head Office in Brasília, Brazil. In Fig. 4 is showed 12 of the 36 species to favor the visualization.

The species used in the agroforestry system described by Armando et al. (2002), and their uses are presented in Table 2. According to the authors the species of this system can be classified into: forest species; biopesticide; fruit species of short rotation; fruit species of medium rotation; annual crops; forage species; cover crops; and ornamental.

Table 2. Common name, scientific name and utilization of agroforestry system species, adopted from Armando et al. (2002).

Common name	Scientific name	Utilization
Pineapple	*Ananas comosus*	Fruit specie of Short rotation
"*Açaí*"	*Euterpe oleraceae*	Fruit specie of Medium rotation
"*Açoita cavalo*"	*Luehea divaricata*	Forest specie
Amaranthus	*Amaranthus caudatus, A. cruentus, A. hypocondriacus*	Forage specie
"*Andiroba*"	*Carapa guianensis*	Biopesticide
"*Alpínia*"	*Alpinia purpurata*	Ornamental
Banana	*Musa cavendish, M. paradisiaca*	Fruit specie of Medium rotation
"*Bastão-do-imperador*"	*Etlingera elatior*	Ornamental
Coffee	*Coffea arabica*	Fruit specie of Medium rotation
"*Canafístola*"	*Peltophoriium dubium*	Forest specie
Cedar	*Cedrella odorata*	Forest specie
"*Copaíba*"	*Copaifera langisdorfii*	Forest specie
"*Crotalária*"	*Crotalaria breviflora, C. juncea, C. paulinea*	Cover crop
"*Cupuaçu*"	*Theobroma grandiflorum*	Fruit specie of Medium rotation

Beans	*Phaseolus vulgaris*	Annual crop
Wild beans	*Canavalha brasiliensis*	Cover crop
Pig beans	*Canavalha ensiformis*	Cover crop
"*Gliricídia*"	*Gliricidia sepium*	Forage specie
"*Helicónia*"	*Heliconia bihai, H. psittacorum, H. chartacea*	Ornamental
Papaya	*Carica papaya*	Fruit specie of Short rotation
Cassava	*Manihot esculenta*	Annual crop
"*Maxixe*"	*Cucumis anguria*	Fruit specie of Short rotation
Corn	*Zea mays*	Annual crop
Mahogany	*Swiethenia macrophylla*	Forest specie
Neem	*Azadirachta indica*	Biopesticide
Cucumber	*Cucumis sativus*	Fruit specie of Short rotation
"*Pupunha*"	*Bactris gasipaes*	Fruit specie of Medium rotation
Ginger	*Zingiber spectabilis*	Cover crop
Tomato	*Lycopersicon esculentum*	Fruit specie of Short rotation

Brienza Júnior et al. (2009) in a survey of 25 years of study about agroforestry in the Brazilian Amazon found that most forest species used in agroforestry systems were: the food species *Theobroma grandiflorum*, *Bactris gasipaes*; the wood species *Swiethenia macrophylla* (Mahogany) *Schyzolobium amazonicum*; and multiple uses species as *Bertholletia excelsa* (Brazil Nut).

Pompeu et al. (2009) showed that the fruit species of higher economic interest that made up the main part of agroforestry systems in Bragança municipality in Pará state. Being the fruits species most used and the most frequent: *Citrus sinensis* (L) Osbeck (Orange); *Cocus nucifera* L. (Coconut); *Euterpe oleraceae* Mart.; *Anacardium occidentali* L.; *Piper nigrum* Vell.; e as agrícolas *Vigna sp.* (Beans); *Manihot esculenta* Crantz (Cassava).

A study developed by Franco et al. (2002), found that the agroforestry systems in Zona da Mata region in Minas Gerais state showed high conservation potential in watersheds when compared to conventional plantation systems of the region. The authors observed that the agroforestry systems could help to reduce the pollution of water resources, caused by runoff of nutrients and chemical products utilized in agriculture, furthermore, the total losses of soil, organic carbon e nutrients of the conventional systems, estimated for one year, were significantly higher than the agroforestry systems.

Conclusion

The Brazilian agroforestry systems have diversified designs, mainly due to the high diversity of biomes, climates, soil types and biodiversity found in our country. The agroforestry system currently most broadcasted is the integration between crops, livestock and forest, also called as agrosilvipasture system, being the configuration of annual crops, cattle and *Eucalyptus spp.* the most popular one. Agrosilvipasture systems using *Pinus spp.* like forest step are also found in the country.

The agroforestry systems with high diversification of species are more practiced by Brazilian family farming. These biodiversity systems provide to farmers the combination of short term income with the annual crops and the investment in wood forest species. The agroforestry systems aimed at family farming provide more soil covering and avoid losses of organic carbon and nutrients by the runoff water more than the conventional plantation systems.

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Landscape remediation after the red mud disaster in Hungary with short rotation forestry

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Introduction

Red sludge is the by-product of bauxite based aluminium production. Bauxite is a mineral raw material that consists of minerals with aluminium content and other components like iron and silicon compounds. When bauxite is processed with the so-called Bayer technology (this technology is used in Ajka) its aluminium content is separated from the other components with sodium hydroxide in strongly alkaline conditions. The produced main product is called alum earth from which metal aluminium is produced using electrolysis. The by-product of alum earth production is red sludge with high iron content and a characteristic colour. As the name suggests, it is a mud-like material with liquid as well as dry matter content. Its further characteristic feature is that it flows easily in its original form, and its flow features change depending on its moisture content and the pressure it is subjected to. Just like in Ajka, red sludge is stored in reservoirs worldwide. Due to the technology applied, a certain proportion of sodium hydroxide used in the separation process remains in the red sludge and causes it to be strongly alkaline. Its pH is typically between 12 and 14 (MTA KK AKI – Hungarian Academy of Sciences Chemical Research Centre).

According to effective EU regulations (94/904/EC directive) red sludge is not considered to be hazardous waste. When it gets into the environment, however, it becomes a potential source of danger threatening the human population, animals and plants as well as the environment (air, water and soil) that comes into direct contact with it. Red sludge threatens the man-made as well as the natural environment due to its strongly alkaline nature (MTA TAKI 2010).

A disaster similar to the one that occurred in October 2010 has not yet happened anywhere so there is no previous experience that could be applied for the recultivation of arable land (Gyuricza et al., 2011, László 2011). In the present study the first soil examination results and the three-step remediation process developed are introduced.

Materials and methods

The region affected by the disaster is situated on the upper watershed area of Marcal in the valley of the Torna stream. Most of the area is covered by loess, muddy, sandy river and slope deposits. The surface soil has a typical light mechanical composition (pebbly sand, sand or loam sand) with occasional muddy, clayey inter layers. On the older and higher areas brown forest soils have formed on the loess deposits while the lower-lying areas have hydromorphic humic gley or river valley soils. The higher territories have pebbly brown soils with thin fertile layers and in smaller patches humic gley chernozem soils. The depth of underground water is generally 2 to 4 meters while in the lower-lying areas 0.5 to 1.0m with seasonal changes. The groundwater normally has calcium-magnesium hydro-carbonate content.

During the survey soil samples were collected from the upper 90 cm of the soil (0-30, 30-60, and 60-90 cm). Sample taking spots were selected so that areas covered by vegetation (clover and corn) and cultivated are both included. Samples were taken three times based on which an average sample was prepared. Basic and nutrient examinations were conducted and the amounts of the most important toxic elements were measured. The elements of the three-step remediation were elaborated on the basis of site specifics, site surveys and laboratory examinations.

Results and discussion

As a result of the disaster the alkaline red sludge covered about 1000 ha of arable land. On site examinations show that the sludge layer stayed on the surface of the soil. It only flowed into occasional cracks and did not mix with the arable soil. The surface pollution of the soils varied depending on the thickness of plant growth, angle of slope, the distance from the place of burst and the speed of the mud current. On already cultivated land surface free from plants the depth of the sludge left behind was a maximum of 1 to 2 cm. Due to the fast flow and in some areas to the high moisture content of the soil the alkaline fraction reached the deeper layers to a very small extent or not at all. We concluded that the heavy metal content of the soil does not reach the pollution limit value of soils and the pH level did not increase significantly in the examined 90 cm deep soil layer (with the exception of the top 10-20 cm) (Tables 1-2.). These areas (about 40 to 45 per cent of the total arable land) can be used again without the removal of the red sludge. The most serious damage occurred in the areas farthest from the site of burst. In these areas the flow of the sludge slowed down and collected in the deeper parts of the surface. It is in these areas that the largest amount of sludge and soil layer had to be removed, and it is also in these areas that the pH level increased.

Table 1. Results of basic pedological and nutrient examinations based on soil samples taken in arable land areas affected by the red sludge disaster (Kolontár, 16 October 2010)

Plant	Depth (cm)	K_A	pH_{KCl}	$CaCO_3$ %	Total salt %	Humus %	NO_2+NO_3-N mg kg^{-1}	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}
Corn	0-20	60	7.3	12	0.05	3.4	3.92	46.4	83.8
	20-40	43	7.2	11	0.07	3.5	4.93	37	63.3
Clover	0-30	47	7.3	9	0.07	2.0	27.1	93.3	97.1
	30-60	45	7.3	11	0.05	1.6	6.0	45	73.1
	60-90	44	7.2	6	0.07	2.2	3.6	80.8	45.5
Plough ed surface	0-30	36	7.8	7	0.13	2.0	27.7	112	83.8
	30-60	43	7.2	5	0.07	2.0	1.1	33	88
	60-90	38	7.4	9	0.02	1.2	2.9	181	40.9

Table 2. Results of soluble toxic element content based on soil samples taken in arable land areas affected by the red sludge disaster (Kolontár, 16 October 2010)

Plant	Depth (cm)	Arsenic	Cadmium	Chrome	Copper mg	Mercury kg^{-1}	Nickel	Lead	Zink
Corn	0-20	9.8	<0.02	28.9	12.4	<0.05	28.2	7.5	63.1
	20-40	20.2	<0.02	36	14.1	<0.05	36.6	7.2	78
Clover	0-30	8.3	<0.02	25.5	10.5	<0.05	26.3	8.5	59.1
	30-60	8.9	0.087	26.9	10.8	<0.05	27.8	5.4	57.8
	60-90	9.9	<0.02	29	9.9	<0.05	27.8	3.8	55.5

Ploughed surface	0-30	8.8	0.039	25.9	8.5	<0.05	23.9	6.5	50.4
	30-60	12.8	<0.02	41.2	12.3	<0.05	37.7	4.8	77.1
	60-90	6.1	<0.02	14.8	6.5	<0.05	19.2	3.8	39.7
***Pollution limit value**		***15***	***1***	***75***	***75***	***0.5***	***40***	***100***	***200***

*In accordance with 10/2000.(VI.2.) KöM-EüM-FVM-KHVM (Ministry of the Environment, Health Ministry, Ministry of Agriculture and Rural Development, Ministry of Transport, Communication and Water) Common Decree

For the revitalization of the arable land area affected by the disaster it is necessary to elaborate processes that are capable of restoring the cultivation area to its original state. The three-step remediation (3R) was developed for this purpose (Fig.1.).

Step 1: The key element of habitat revitalization is the recovery of soil biological activity and the prevention of the dusting out of the red sludge. In order for these to happen, a special soil improving and yield enhancing product (compost-turf mixtures) was used (1st remediation step). This step increased the biological activity of the soils as well as their nutrient storage capacity thanks to the high adsorption capacity, increased the immunity of energy plants (willow and poplar) against germs and pests, established a stable soil structure and improved the water, heat and air management of soils. After spreading the material, it needs to be turned into the soil with a disc (to a depth of max. 10 cm).

Step 2: Right after the compost-turf mixture was spread annual plants were sown on the area (2nd remediation step), which ensures the quick cover of the soil with vegetation and organic matter replacement. For this purpose, undemanding plants with fast growth rate (e.g. triticale and rye) were used. In spring the green plant mass will be crushed with stem shredder, which will result in a high volume of mulch cover.

Step 3: Creating a ligneous plantation (3rd remediation step). Planting is possible with 150-200 cm long stick cuttings or 20-22 cm long plain cuttings. A stick cutting is a one-year-old ligneous plain cutting without roots planted 40-50 cm deep. The foliage that falls in the autumn protects the soil surface and provides organic matter. The plants can be first harvested in 2 years and then for the next 10 to 16 years the biomass can be cut with the same cutting cycle.

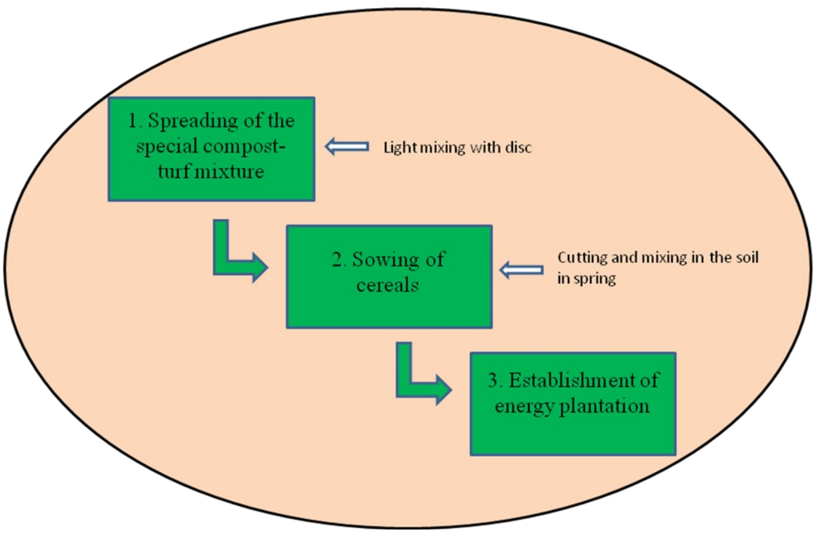

Fig. 1: The schematic of the three-step remediation (3R)

Conclusions

In summary, it can be concluded that the disaster caused less damage in non-residential areas then it could have been expected based on the damage caused in residential areas. The area can be made suitable even for food raw material production in a short time (1-2 years). In spite of this it is necessary to alter soil use completely (through growing energy plants with the role of landscape rehabilitation and regeneration) due not so much to habitat damage but to market conditions and psychological impacts. For selecting the most suitable energy crop various aspects need to be considered (ecological, market, social and socio-economic). Based on these, the cultivation of ligneous energy crops with a systemic approach is the most efficient and secure solution. The specifics of the site make the area absolutely suitable for growing willow, poplar, acacia and various other energy crops. The buying up of the biomass can be done by the nearby power plant. At the same time, the heat energy needs of the rebuilt settlement districts could thus be supplied from renewable energy sources.

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Short rotation forestry: End-use conflicts and potential for positive outcomes in a developing country context

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Abstract

Short rotation forestry can be viewed as both providing a renewable source of fuel and means of sequestering carbon if managed effectively but its impact will vary according to climate, soil type, species used, management practices, the land use it is replacing, and end use. Not only will its impact on carbon sequestration vary according to site due to management and local conditions but the socio-economic impact will vary as well. This presentation is based on a report produced for the Benwood project entitled 'Landuse Management Standards' which means to address the ethical concerns about plantation management rather than giving the ideal conditions and management of SRF plantations for production; these areas are more deeply addressed in the associated Benwood project documents 'Best Practices' and 'EU Guidelines'. Agricultural land is continuously expanding and becoming more intensively cultivated due to population increase and the fact that the majority of developing country populations continue to rely heavily on agriculture as their main means of livelihood. In relation to short rotation forestry, the important points to consider in a developing country context are sustainability of the system, impact on local communities, end-use conflicts and competition between different land uses. Plantations are often imposed with little consideration for the local environment and community and land-grabs have been cited as causing problems across African countries through diminishing resources available for populations that rely on the land for their livelihood needs. There is an apparent need for deeper understanding of local contexts and ensuring that project documentation reflects what is experienced on the ground so that lessons can be learnt rather than brushed under the carpet. Case studies to be discussed in relation to short rotation tree cultivation in smallholding systems and plantations, energy and food conflicts and potential for positive outcomes in an African context.

Keywords: Food, energy, agroforestry, local systems, short rotation forestry

Note: More information on this topic can be found in the Benwood document on "*Land Use Management Standards".*

Additional full papers

(no speech held on these papers)

Utilization of fast-growing wood from thinning and pruning as oriented strand board raw material

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Introduction

Plantation forest of fast-growing species have become very common in many tropical countries. In Indonesia, there are many types of plantation forests, namely industrial plantation forest (Hutan Tanaman Industri), manmade forest (Perum Perhutani), and community forest (Hutan Rakyat). Either thinning or pruning is the usual activity in plantation forest. In Indonesia, the utilization of the wood originated from thinning and pruning activities was still limited, in fact just for wood energy.

Rowell (1998) stated that one of the trends today is bio-based resources coming from small diameter trees, including plantation residues, thinning, and pruning could be utilized for composites products, i.e. fiberboard, particleboard, oriented strand board (OSB), and comply.

OSB as structural material be designed as plywood substitution (Nishimura et al 2004). In Canada and USA, OSB was used widely for roofing and sheating in settlement and commercial building (Lowood 1997), furniture and industrial building (APA 2000), room insulation, board, stairs, and engineered wood I-joist (CWC 2006), even in China, OSB has been developed for west-style housing (Wolcott et al 1997).

In order to optimize fast growing wood originated from plantation forest as OSB raw material, this research should be considered. This paper specifically evaluates the physical and mechanical properties of OSB made of three fast growing wood, especially from thinning and pruning, which are important for the plantation forest in Indonesia.

Material and methods

Raw material

In this research, the wood was utilized as raw material for Oriented Strand Board (OSB). The wood, namely acacia (A*cacia mangium* Willd) represented industrial plantation forest, eucalyptus (*Eucalyptus sp.*) representing manmade forest, and gmelina (*Gmelina arborea* Roxb.) representing community forest, were converted into strands form by a disc flaker (Fig. 1).

Fig. 1: Disc flaker which converted wood billets into strands

Investigated strand properties

Properties of strands as OSB raw material were investigated: strand appearance, measurement of dimension, and physical properties.

Wettability and adhesiveness

Wettability by measured the contact angle between the adhesive and the wood strands. Resin solid content be measured based on Japanese Industrial Standard (JIS) K6833-1980

Board manufacture and evaluation

OSB was produced of three plies, equivalent to 3-layers of veneer in plywood, with 9 mm target thickness, therefore the ratio of strand weight in face : core: back was 1:1:1. The strands of each of its layers aligned parallel to one another, but perendicular to those in adjacent layers, like the cross-laminated veneers of plywood. It is this perpendicular orientation of different layers of aligned strands that gives OSB its unique characteristics and allows it to be engineered like plywood (Lowood, 1997).

Mat forming methods in face and back were lengthwise and the core was widthwise. OSB was pressed at 25 kg/cm^2 for 15 minutes at 160^{0}C. Target density was 0.75 g/cm^3. Phenol Formaldehyde (PF) resin adhesive level was 7% based on oven dry strands weight. It was formulated by PT. Duta Pertiwi Nusantara, Pontianak, West Kalimantan, Indonesia.

OSB was conditioned for 2 weeks and then sawed into samples for physical and mechanical testing. Totally, there were 15 board samples with 5 replications for each wood type.

Before evaluation, all of samples were measured in dimension and weight in order to get the density. Thus, in the final testing, the values had to be corrected for density differences.

Both of physical and mechanical properties were investigated based on Japanese Industrial Standard (JIS) A 5908-2003 for particleboard 24-10 type. The mechanical properties, include bending test (MOE and MOR) using centre loading by Instron Universal Testing Machine.

Results

Strands appearance

The appearance of strands was quite diverse. The color of the acacia strands was a combination of white and dark brown. The eucalyptus tends light brown, and the gmelina tends yellowish white (Fig.2).

(a)

(b)

(c)

Fig. 2: Strands appearance produced from disc-flaker (a) acacia wood strands, (b) eucalyptus wood strands, (c) Gmelina wood strands

Table 1 shows a comparison of the strands. They varied in dimension, specific gravity, aspect ratio, and slenderness ratio. Dimension of strands matched with the suggestion of Marra (1992) of 0.5-3 inches (1.27-7.62 cm) in length and of 0.25-1 inches (0.64-2.54 cm) in width. Unfortunately, the thickness did not match. This was because of the disc flaker. Ideally, for strands making a strander should be used.

Aspect ratio was the ratio of length and width of strands and slenderness ratio was the ratio of length and the thickness of strands (Nishimura et al, 2004). Both of aspect ratio and slenderness ratio showed the same tendency. The highest was gmelina and the lowest was acacia.

Table 1. The average dimension and physical properties of strands

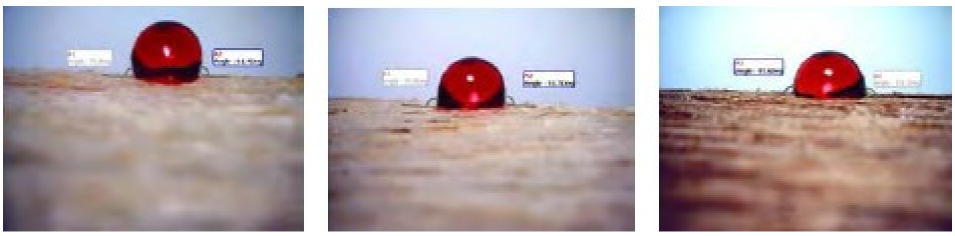
No	Properties	acacia	eucalyptus	gmelina
1	Dimension a. Length (cm) b. Width (cm) c. Thickness (cm)	 6.98 (0.09) 2.31 (0.11) 0.12 (0.03)	 7.01 (0.09) 2.19 (0.13) 0.10 (0.02)	 7.03 (0.06) 2.16 (0.07) 0.10 (0.02)
2	Weight (g)	0.79 (0.27)	0.89 (0.31)	0.66 (0.17)
3	Specific gravity	0.41 (0.09)	0.57 (0.14)	0.45 (0.06)
4	Aspect ratio	3.03 (0.15)	3.21 (0.19)	3.26 (0.12)
5	Slenderness ratio	64.09 (25.52)	73.39 (17.63)	76.42 (19.95)

Remarks: The data were averaged from 100 samples and the values in the parentheses are the standard deviation.

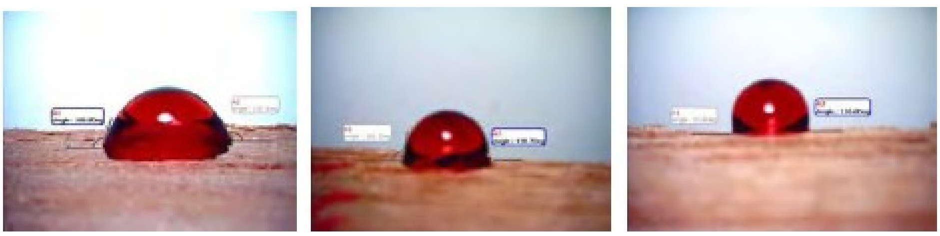
Strands wettability

In order to know the wettability of wood strands and the adhesive, the contact angle measurement was investigated (Figure 3). The wettability is an important parameter in OSB production because of water and extractives in wood. Vick (1999) stated that most wood adhesives contain water as carier, therefore, they donot properly wet, flow, and penetrate extractive-covered surfaces. The acidity of extractives of some hardwood can interfere with the chemical cure of adhesives. The acid may accelerate the cure of an alkaline phenolic adhesive, causing the adhesive to gel prematurely and reducing its ability to wet, flow, and penetrate. In contras, normal polymerization of an acidic adhesive, can be retarded by an alkaline wood surface, which would compromise the integrity of the adhesive film and bond.

Previous works by Ruhendi (1983) and Sulistyawati & Ruhendi (2008) showed that wood wettability has relationship with the internal bonding both in plywood and in laminated board.



(a)



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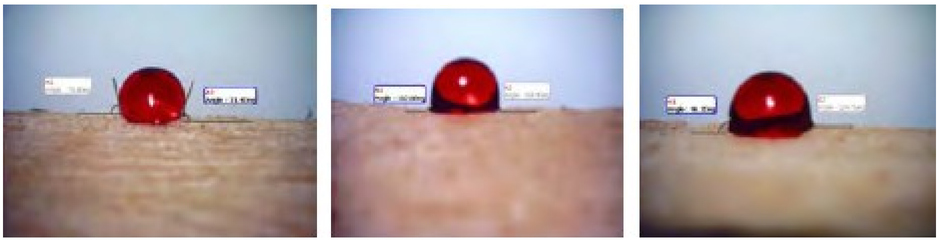

(c)

Fig. 3: Wettability of strands with Phenol Formaldehyde (PF) adhesive (a) acacia, (b) eucalyptus, (c) gmelina

Table 2 shows the results of contact angle measurement between wood strands and the Phenol Formaldehyde (PF) adhesive. These results are to be expected since the surface of the wood strands is shown in Fig. 4.

Table 2. Result of contact angle measurement between wood strands and PF adhesive

Replication	**Angle (^{0})**		
	acacia	**eucalyptus**	**gmelina**
1	101.10 98.60	73.20 59.70	101.60 108.60
2	88.40 88.30	79.90 51.30	67.40 71.60
3	84.40 78.90	86.40 63.40	83.90 55.30
Average	89.95	68.98	81.40

In Fig. 4 the results of a photomicroscopic examination of the surface of the wood strands are shown.

(a) (b) (c)

Fig.4: Surface of wood strands captured via photomicroscope (a) acacia (b) eucalyptus (c) gmelina

Results of the measurement of resin solid content (RSC) of PF adhesive showed in Table 3.
This parameter is important for the quality of OSB. Vick (1999) stated that a formulation of wood adhesive consists of a mixture of several chemically active and inert materials that vary in proportion with the basic adhesive polymer, which enhances performance, whether it concerns working characteris-

tics, strength properties, shelf life, or durability. Water is used as the carrier for most wood adhesives, primarily because water readily absorbs into wood, is inexpensive, and is free of toxicity problems.

Table 3. Resin solid content of PF adhesive

Replication	Initial weight (g)	Oven dry weight (g)	RSC (%)
1	1.55	0.68	43.87
2	1.56	0.69	44.23
3	1.56	0.71	45.51
Average			44.54

Physical properties of OSB

Results of physical properties test on OSB are presented in Table 4. The density values of all OSB met the requirements of JIS A 5908-2003. Unfortunately, they were below on target (0.75 g/cm^3). This phenomenon may be related to the variation of wood strands specific gravity (Table 1).
acacia was 0.41±0.09, eucalyptus was 0.57±0.14, and gmelina was 0.45±0.06. The specific gravity is needed to know the compression ratio. Bowyer et al (2003) stated that the best compression ratio between 1.20-1.60.

Moisture content tendencies are the same for all the OSB. These results were to be expected because wood strands are lignocellulosic material, hygroscopic, and the RSC (resin solid content) of the adhesive is the same for all the OSB (about 44.54%) (Table 3).

Thickness swelling after 24 hours of water immersion failed to meet the minimum requirement set forth by JIS standard. In 24 hours of water immersion, the OSB absorbed much water. During this process, the low density strands swell. This produced internal stress to the cured adhesive which acts as a binder for the OSB. If the internal stress was larger than the cured adhesived forces, the residual stress during hotpress were released and the thickness of OSB will be increased. The strongest swelling in thickness on OSB was found with eucalyptus. This phenomenon could be explained by the wettability parameter (Table 2). Results of measurement of contact angle showed that eucalyptus was easy to wet and absorb easily both, PF and water.

There is no prerequisite for water absorption according to JIS A 5908. The testing was done as additional information. Values of water absorption corresponded to thickness swelling.

Table 4. Physical properties of OSB

Species of wood strands	Density (g/cm^3)	Moisture content (%)	Thickness swelling 2 hours (%)	Thickness swelling 24 hours (%)	Water absorption 2 hours (%)	Water absorption 24 hours (%)
acacia	0.65	9.64	10.14	38.94	14.27	62.43
eucalyptus	0.68	9.47	17.39	40.67	17.79	72.94
gmelina	0.63	9.16	7.54	26.16	12.59	63.71

JIS A 5908-2003	0.40-0.90	5-13	-	Max 25	-	-

Remarks : The data were averaged from 5 replications and JIS A 5908-2003 was the Japanese Industrial Standard for OSB (particleboard type 24-10).

Mechanical properties of OSB

The mechanical properties, which consist of the strength testing includes dry internal bonding and static bending test (dry and accelerated-aging modulus of rupture/MOR and modulus of elasticity/ MOE) were tested in both lengthwise and widthwise generally fulfilled the JIS, except for eucalyptus wood. The best OSB was made of gmelina, which has a strength retention (SR) above 50% for MOR. Table 5 summarized the mechanical properties of OSB.

Table 5. Mechanical properties of OSB

Species of wood strands	Internal bond (kgf/cm^2)	Dry MOR lengthwise (kgf/cm^2)	Dry MOR widthwise (kgf/cm^2)	Dry MOE lengthwise (kgf/cm^2)	Dry MOE widthwise (kgf/cm^2)	SR MOR (%)		SR MOE (%)	
acacia	3.11	320	170	3.55 x 104	0.89×10^4	39	76	30	43
eucalyptus	3.30	203	81	2.62×10^4	0.48×10^4	46	60	23	56
gmelina	4.76	278	134	3.57×10^4	0.87×10^4	57	65	32	49
JIS A 5908-2003	3.10	Min 245	Min 102	4.08×10^4	1.33×10^4	-	-	-	-

Remarks: The data were averaged from 5 replications, MOR was modulus of rupture, MOE was modulus of elasticity, SR was strength retention, and JIS A 5908-2003 was the Japanese Industrial Standard for OSB (particleboard type 24-10)

Regarding the internal bond strength, it became evident, that among the tested species, gmelina performed best. This may be influenced by both the aspect ratio and slenderness ratio of the strands. Compared to the others, gmelina strands have the highest value of this ratio (Table 1).

In general, both MOR lengthwise and widthwise values on OSB eucalyptus failed to meet the minimum requirement set forth by the JIS standard. This is because the eucalyptus was easy to wet by PF (Table 2) and the strands had a rough surface (Figure 4), consequently the PF penetrated into the strands and failed to form glue-lines.

MOE properties performed the same trends with MOR. The values of eucalyptus OSB showed the worst MOE comparing with acacia and gmelina.

Not only MOR but also strength retention of MOR of gmelina showed relatively high values. This is because the direction of gmelina fiber was relatively straight. Fiber orientation is the direction along the long axes of the dominant longitudinal cells or fibers in a piece of wood. Koch (1985) stated that fiber orientation 10^0 will decrease tensile force up to 49% and 20^0 will decrease tensile force up to 97%. Besides that, gmelina strands were bigger than acacia and eucalyptus strands which supported the high bending and elasticity of the according OSB (Younquist, 1999; Nishimura et al 2004)

Conclusion

The properties of wood strands that influenced the final properties of the OSB consist of shape including aspect ratio and slenderness ratio, wood species, specific gravity, and the interaction with the adhesive (wetting and penetrating of the adhesive into wood strands).

According to the results of the experiments and these parameters, the best OSB was made of gmelina strands.

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Utilization sengon wood as face/back veneer on comply products

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Introduction

Sengon (*Paraserianthes falcataria* L.Nielsen) is one of the fast growing species planted in Indonesia. In this research, sengon wood was converted into veneers by rotary cutting. The veneers be used as face and back surface of comply products which their core was Medium Density Fiberboard (MDF) produced by recycle papers, namely newspaper, book paper, and office paper.

Previous work by Siagian & Nuryawan (2010) reported that fiber made of recycled book paper was the longest than newspaper and office paper in length dimension. However, all of the fiber was classified into class III according to Indonesian Forest Products Research Report (Laporan Penelitian Hasil Hutan) No.75 in year 1976.

In this research, effect of sengon veneer to the quality of comply was investigated. We hope that this research will contribute to the knowledge the utilization of sengon wood as face/back veneer on comply.

Material and methods

The veneers be used as face and back surface of comply products which their core was Medium Density Fiberboard (MDF) produced by recycle papers, namely newspaper, book paper, and office paper. The comply was produced, with 10 mm target thickness and 0.75 g/cm^3 density target. The comply was pressed at 35 kg/cm^2 for 15 minutes at 155°C. Level of isocyanate resin adhesive 8% based on oven dry fiber and veneer weight. The board were conditioned for 2 weeks and then be sawed to be samples for physical and mechanical testing. Before evaluated, all of the samples be measured their dimension and be weight for density. Thus, in the final testing, the values must be corrected for disappear of density variation. Japanese Industrial Standard (JIS) A 5905-2003 for fiberboard was used as standard.

Results

Results of this research showed both of physical and mechanical properties fulfilled JIS standard, classified decorative MDF veneer overlay type 15. Unfortunatelly, the internal bonding was failured because of the volumenous of the core and the range values were 0.14-0.20 N/mm$^{2.}$ The performance of sengon veneer produced by rotary cutting is shown in Fig. 1.

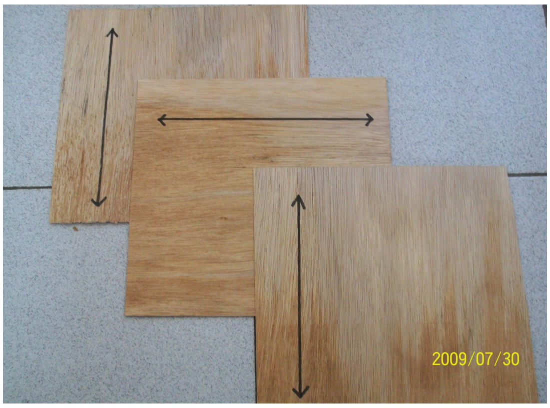

Fig. 1: Performance of sengon veneer produced by rotary cutting

Fig. 2 shows the performance on comply made of recycled paper as the core and sengon veneer as face/back layers.

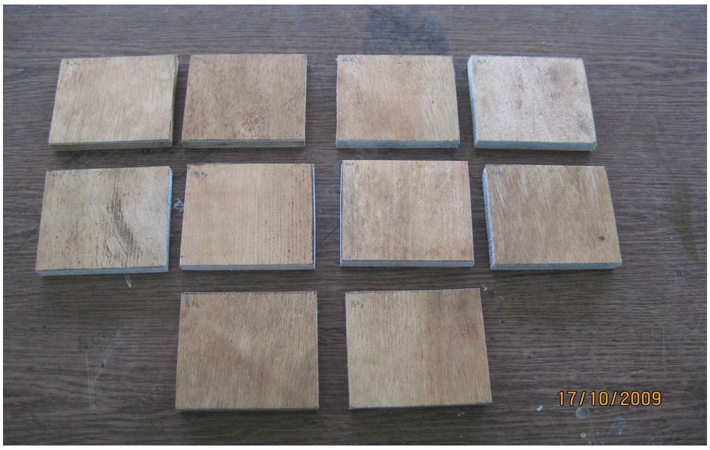

Fig. 2: Performance on comply products which sengon veneer as face/back layers

Physical properties of comply

Table 1 summarized the physical properties of comply. The density and moisture content fulfilled the JIS A 5905-2003. Unfortunately, the dimensional stability performed poor in thickness swelling both in 2 and 24 hours. This phenomenon related to characteristics of fiber made of recycled paper.

Table 1. Physical properties of comply

Physical Properties	Comply core newspaper	Comply core book paper	Comply core office paper	JIS A 5905-2003
Density (g/cm^3)	0.58	0.55	0.57	Min 0.35
Moisture content (%)	9.73	7.94	7.23	5-13

Thickness swelling 2 hours (%)	33.78	17.21	21.58	-
Thickness swelling 24 hours (%)	37.76	20.78	24.24	Max 12
Water absorpsion 2 hours (%)	99.59	52.25	49.98	-
Water absorpsion 24 hours (%)	127.21	85.41	84.24	-
Linear swelling 2 hours (%)	1.98	1.55	1.14	-
Linear swelling 24 hours (%)	2.34	1.81	1.22	-

According to previous work by Siagian & Nuryawan (2010), recycled paper have relatively uniform in dimension. Based on LPHH classification, all of the fiber be classified into class III. Table 2 showed the values of the dimension of recycled paper which used as core in this product.

Table 2. Dimension of fiber originated from recycled paper

Fiber origin	**L (µm)**	**d (µm)**	**l (µm)**	**w (µm)**
Newspaper	1158,07	17,43	4,02	6,71
Book paper	1265,08	17,12	6,22	5,45
Office paper	1000,97	16,17	7,06	4,55

Remarks :L = length, d = diameter, l =lumen diameter, w= wall thickness

Mechanical properties of comply

Table 3 summarized the mechanical properties of comply. The quality of comply was influenced not only the veneer but also the core.

Table 3. Mechanical properties of comply

Mechanical Properties	**Comply core newspaper**	**Comply core book paper**	**Comply core office paper**	**JIS A 5905-2003**
Screw holding power (kg)	597.47	553.97	528.91	Min 400
MOE (N/mm^2)	2252.08	1912.88	1953.05	Min 2000
MOR (N/mm^2)	16.70	14.19	12.75	Min 25
IB (N/mm^2)	0.20	0.19	0.14	Min 0.4

Remarks: MOE = modulus of elasticity, MOR = modulus of rupture, IB = internal bonding, JIS = Japanese Industrial Standard

If we investigated the derivative of fiber dimension originated from recycled paper which shown in Table 4, the values relatively different. Based on result in Tabel 3, comply made of newspaper fiber as the core met the JIS A 5905-2003 for screw holding power and MOE. So, either screw holding power or MOE was influenced by runkle ratio and muhlstep ratio.

Table 4. The derivative of fiber dimension

Parameter	Newspaper	Office paper	Book paper
Runkle Ratio	3.34	1.29	1.75
Felting Power	66.44	61.90	73.92
Flexibility Ratio	0.23	0.44	0.36
Coefficient of Rigidity	0.38	0.28	0.32
Muhlsteph Ratio	94.69	80.93	86.79

Conclusion

The quality of comply product was influenced not only by the veneer as face/back layers but also by the core. In general, sengon veneer couldnot hold the dimensional stability especially if the core made of paper. If we generally conclude, the core was influenced by both of fiber dimension and derivate fiber dimension.

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The impact of wild animals on SRC in Germany – a widely underestimated factor

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1. Introduction

Since the beginning of the 21st century there has been a renaissance of poplars (*Populus sp.*) and other fast growing tree species such as willows (*Salix sp.*) and black locust (*Robinia pseudoacacia*) in Germany; approximately 4,500 ha of short rotation coppice (SRC) have been established, mainly on agricultural land. The main focus of the scientific work done since then has been on cultivation systems, the choice of tree species and clones, the estimation of yield and the benefits of SRC in comparison to other agricultural crops such as maize, sugar beet, potatoes and grains. However, the influence of pests, diseases and wild animals has been widely underestimated. This paper will give a more detailed view on the impact of wild animals on SRC.

Over the last seven years, P&P Forest Tree Nursery has established and observed more than 1,500 ha of SRC in Germany. During this time we have recorded and identified a variety of wildlife-related damage in various types of SRC. It ranged from local damage due to rubbing by different deer species (fallow deer/*Dama dama*, red deer/*Cervus elaphus* and roe deer/*Capreolus capreolus*), to repetitive browsing on a 40 ha SRC with black locust over five years, and up to the complete destruction of SRC by deer browsing in the winter of 2010-2011 in the federal states of Brandenburg, Mecklenburg-Vorpommern and Hessen.

Fig. 1: Roe deer (Capreolus capreolus) on a winter barley field; (Photo: www.jagd.it)

Fig. 2: Red deer stag (*Cervus elaphus)*
(Photo: www.wildundfreizeitpark.de)

Fig. 3: Fallow deer herd (*Dama dama*)
(Photo: www.vierseithof-braune.de)

2. Examples of deer damage on SRC on different sites in Germany

In the following, several examples of deer damage to SRC as well as the results of the investigation of food preferences in SRC sample plots will be described. All sites represent typical agricultural sites for SRC in central and north-eastern Germany (Fig. 4). Except for the sample plots, the sites are at least 5 ha in size. Thus, damage by wild animals due to the small size of the plantations can be excluded.

Fig. 4: Locations of the mentioned SRC sites in Germany

2.1 Browsing on black locust in Kostebrau (Brandenburg)

The energy forest of Kostebrau is located in the south of the federal state of Brandenburg (Fig. 4, point 1). It was planned in 2006 on 360ha of a post-mining area (Landgraf et al., 2006). Soils of post-mining areas are characterized by a pronounced heterogeneity of substrates (i.e. silt, loam and sand). Due to this great variety of substrates even on smallest areas, a wide mosaic of sites is visible. These sites are characterized by an unstable soil structure, a lack of organic substance, low soil microbial activity and the lack of nutrition cycles. The region of south Brandenburg has a mean annual precipitation of 550 mm, with about 300 mm within the vegetation period. The mean annual temperature is about 9.2 ∞C.

In accordance with the recultivation progress of the former brown coal pit, the energy forest is to be established between 2007 and 2014. In 2007, the first 80 ha of energy forest were established; 40ha with black locust (*Robinia pseudoacacia*) and 40 ha with poplar (*Populus sp.*). Due to the size of the site and the expected costs, no fence was build.

After a very good start in the first year - the survival rate was over 95% - all black locust plants were heavily browsed by roe deer and red deer. Until 2011 the whole black locust stand of 40ha was repetitively browsed and kept at a low height (Fig. 5, Fig 6). According to Landgraf et al. (2007) and Ertle et al. (2008), the yield to be expected for black locust is 8t absolute dry mass per ha per year (t_{adm} ha-1 a-1). Thus, for the period of five years a total loss of 1,600 t_{adm} is to be calculated for the black locust site. Assuming a price of € 90 per t_{adm} , this means a financial loss of € 144,000.

Fig. 5: SRC with black locust after 5 years

Fig. 6: Single unbrowsed plants show the growth potential of black locust

2.2 Browsing and breaking damage on poplar in Ragow (Brandenburg)

From the end of the 19th century until the 1980s, sewage was irrigated on an area south of Berlin, near the village of Ragow (Fig. 4, point 2). This sewage disposal caused significantly site changes. Large humous horizons developed in the top soil. Beside an increase of the water holding capacity, a lot of nutrients were also accumulated by the sewage irrigation. Therefore the soil fertility was increased over a period of nearly 100 years (Landgraf and Böcker, 2010). However, the concentration of heavy metals was also increased by this management. Thus, cultivation of food crops on these sites is no longer possible. The establishment of SRC is considered to be an alternative for a successful and sustainable land use management. Thus, an area of 296 ha SRC, with poplar (*Populus sp.*) and black locust (*Robinia pseudoacacia*), has been established in the last three years (Fig. 7). The mean annual precipitation and temperature are comparable to that in Kostebrau.

In the spring of 2011 heavy browsing damage, including the breaking of shoots was recorded mainly in 1 year old poplar stands (Fig. 8, Fig. 9). The harsh winter of 2010-2011, together with a high density of roe deer and red deer are considered to be the reasons for this. Interestingly, big differences in damage intensity were found on the two sides of this area, which are separated by a motorway. East of the motorway, hunting is done following the goal of game control. In consequence the damage here is significantly lower than in the area west of the motorway, where private leaseholders with the aim of trophy hunting are trying to preserve a large deer population.

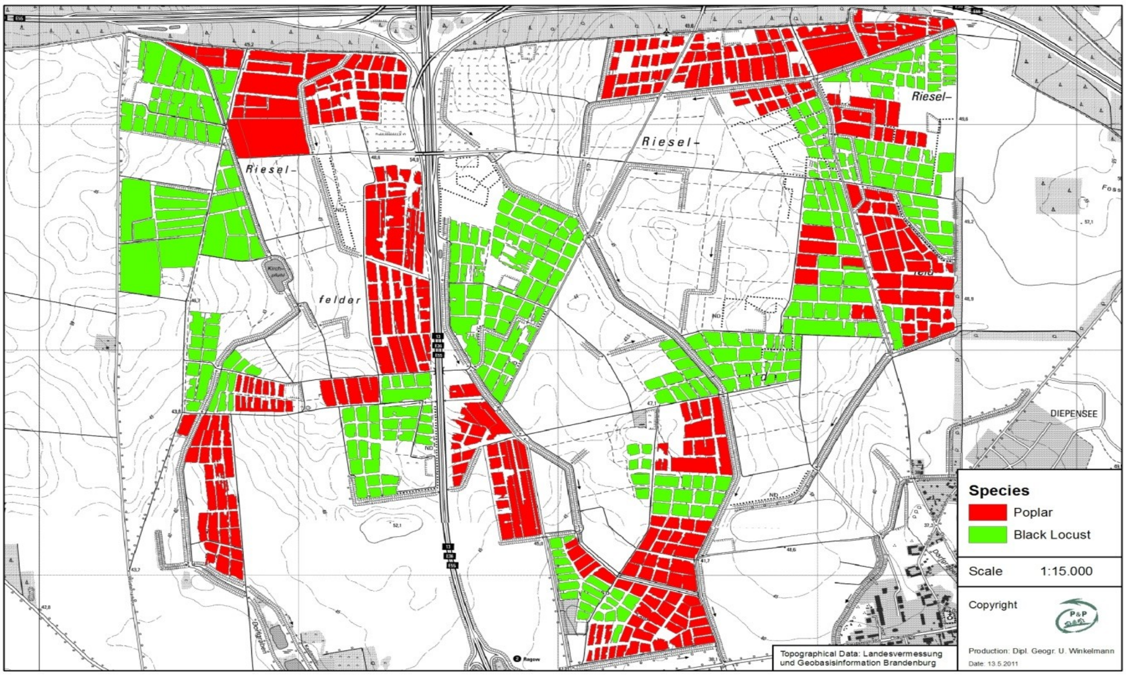

Fig. 7: Overview of the SRC sites with black locust and poplar on the former sewage fields south of Berlin

Fig. 8: Breaking damage on a one-year-old poplar shoot in Ragow, February 2011

Fig. 9: At some sites almost 100% of the shoots were broken down by deer roe deer and red deer in winter10/11

2.3 Browsing damage on black locust in Bennin (Mecklenburg-Vorpommern)

This site is located approximately 70 km south east of the city of Hamburg (Fig. 4, point 3) and characterized by an annual precipitation of 620 mm and temperature of 8.4 ∞C (meteorological station in Schwerin). The soil can be described as a slightly loamy sand. In 2009, SRC with black locust was established on an area of 13.1 ha. Over the following two years the trees had no chance to gain height due to the very large population of roe deer, red deer and fallow deer on this site (Fig. 10, Fig. 11).

Fig. 10: Heavily browsed black locust

Fig. 11: Two-year-old repetitively browsed black locust

2.4 Browsing and breaking damage on poplar in Weimar/Allna (Hessen)

The SRC sites near the village of Weimar/Allna, 8km south of the town of Marburg in the federal state of Hessen, were established in the spring of 2010 using different clones (Fig. 4, point 4). The area is characterized by an annual precipitation of 696 mm and an annual temperature of 8.7 ∞C. The soil is a silty loam and therefore of better quality than the aforementioned sites.

The early and harsh winter of 2010-2011, with a lot of snow, caused a big lack of food for wild animals. Thus, they used the new established SRC for feeding, which resulted in heavy damage on up to 100% of trees per field. The height loss ranged from 43.7% to 72.9% (Table1).

Table 1. Effect of wild animals on the height of poplar on the SRC sites in Weimar/Allna

Field name/ poplar clone	mean height at the end of the vegetation period [m]	mean height after deer damage [m]	growth loss [m]	growth loss [%]
field 1/MAX 3	1.18	0.32	0.86	72.88
field 2 MAX 3	1.58	0.89	0.69	43.67
field 3/Androscoggin	0.66	0.27	0.39	59.09
field 4/Androscoggin	0.86	0.25	0.61	70.93

Fig. 12: Hay rack in the middle of an SRC site

Fig. 13: Deer damage in a one year old poplar stand in Weimar/Allna

The local hunters seem to have contributed to the heavy damage. They placed hay racks and other game feeding facilities right in the middle of a plantation, contrary to the law and “common practice” in Germany (Brunner and Landgraf, 2011).

However, a positive example with only marginal influence by deer and a maximum possible growth rate is visible in Hessen too (Fig. 14). Thoughtful hunting management and the immediate vicinity to a village contributed to the good results.

Fig. 14: SRC in Hessen at the beginning of the second vegetation period without influence by deer (Photo: Ruthenbeck, 2011)

3. Food preferences of wild animals

On SRC sample areas, established for various research purposes, the clone-related browsing damage on poplar and willow was also investigated. Each sample area had a size of about 0.15 ha and consisted of a separate poplar plot with five and a willow plot with three different clones planted randomly with a clone change every fifth plant. Data for willow was collected on two sites: one located in south Brandenburg and one in the south of Saxony near the Ore Mountains. Roe deer occur at both sites. Data for poplar was also collected on a third site, situated in the southwest of Brandenburg. Here, red deer occur as well as roe deer.

In December of the establishment year, the plants were monitored for browsing damage. The results are shown in Figure 15 as total for all sample sites. On both willow plots, all three clones showed a high percentage of browsing damage without any visible preference for one of the clones. The poplars were generally less browsed, confirming the known preference of willow over poplar by deer. Furthermore, the results on poplar suggest the existence of food preferences among the clones. The two clones ‘Androscoggin’ (*Populus maximowiczii* x *Populus trichocarpa*) and ‘Muhle Larsen’ (*P. trichocarpa*) were significantly more browsed than the three ‘Max’ clones (Populus maximowiczii). Further research on those food preferences may help to establish SRC with a low risk of being damaged by wild animals.

Black locust was not included in these investigations. However, observations on several SRC showed that black locust, similar to willow, is highly preferred over poplar, as long as their sprouts and spines are still soft enough.

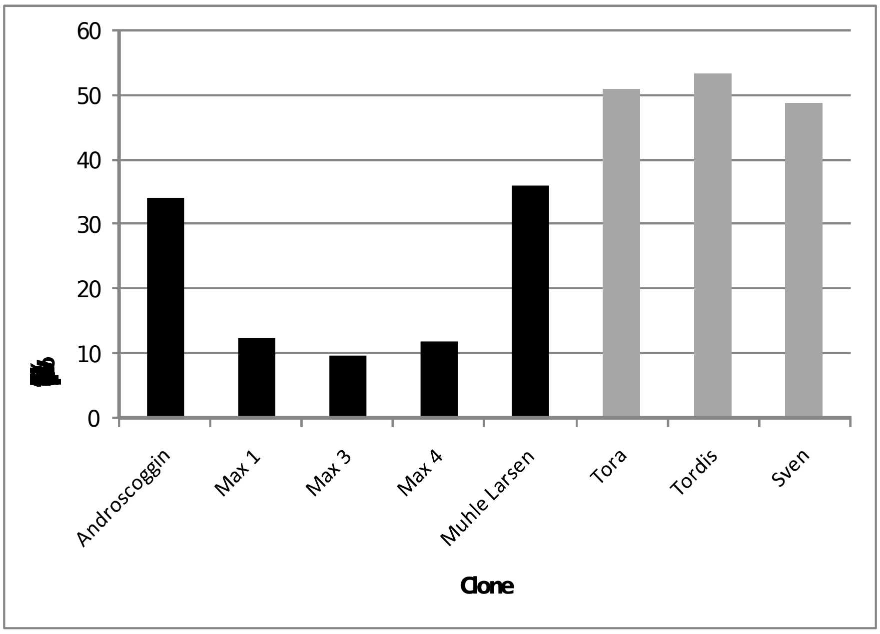

Fig. 15: Food preferences of deer for different poplar (black) and willow (grey) clones as recorded in randomly planted sample plots

4. Conclusion

Our observations confirmed that SRC provides high quality food for several deer species (Bergström & Guillet, 2002) and that under certain circumstances, such as high deer density and unfavourable weather conditions, browsing by wild animals can lead to severe damage in SRC and put the success of the plantation at risk.

In practice, the management of such damage has been characterized by an appalling lack of awareness of land users on one hand and of administrative authorities on the other. This is partly explained by recent changes to existing law (e.g. by the reform of German forest law in July 2010). Nevertheless, the great damage suffered by SRC over the past five years can also be attributed to the ignorance of hunters, farmers and authorities regarding the production of wood as a component of agricultural management.

The construction cost of fences as deterrents against wild animals is economically prohibitive. Moreover, the use of repellents would be a very time-consuming strategy whose success cannot be guaranteed. The consideration of food preferences when choosing tree species and varieties may prove beneficial for the reduction of damage by deer species. Generally speaking, the successful establishment and management of SRC can be ensured only by building positive cooperation with local hunters. The practice of having shooting plans in Germany has to be questioned. In addition to these proposals, the classification of SRC as a conventional agricultural crop, rather than a special crop, must be accepted by several kinds of administrative authorities (e.g. ministries, offices of farming, offices of forestry, etc.). Without this acceptance, establishing SRC of satisfactory quality will prove difficult and bad examples of SRC will only serve to promote further negative attitudes towards it.

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Results of testing various biomass estimation methods for short rotation coppice with poplar (suitable to Southern German conditions)

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Introduction

Short Rotation Coppice has been a growing sector for German farmers and other operators over the last couple of years. As of 2009 the total area of Short Rotation Coppice in Germany covers about 2300 hectares, about 280 hectares are located in Bavaria as of 2010 (InVeKoS). Despite the relatively small total area of SRC in comparison to other agricultural crops, there are many independent SRC operators who have been cultivating Short Rotation Coppice successfully since years. Decent knowledge and experience has been developed amongst operators since then. Whereas the main focus of SRC science lies in fundamental research, transdisciplinary elements as the integration of the experience of SRC operators, their concerns and suggestions have not been considered thoroughly so far.

With our research project “Analysis of the socio-economic SRC potential in Bavaria” we investigate the existing SRCs in Bavaria, profit by general longtime experience of farmers and gain knowledge about what kind of agricultural land is used under given economic conditions. Finally we collect detailed data on biomass production by **measuring biomass yield under conditions of practice** to close gaps in expertise on biomass yield amongst practitioners as well as scientists.

In terms of economic operations and due to time constraints an accurate and efficient biomass yield estimation technique is required. The technique needs to be easy to handle and preferably non-destructive.

Figure 1 shows the total of SRC area in Bavaria per Landkreis [ha]. The SRC distribution is very inhomogeneous with its mass centre in the southern part as the map demonstrates. On basis of SRC distribution within Bavaria, investigation areas for this research project were chosen in regions with the highest number of total area.

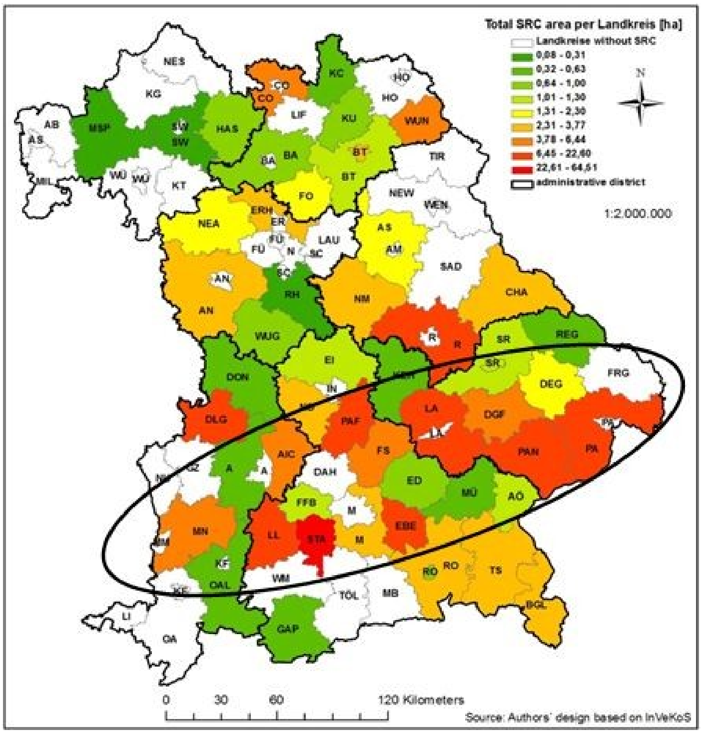

Fig.1: SRC in Bavaria marked region shows mass centre

Biomass yield is one of the most important factors contributing to a profitable cultivation of SRC (Sheridan, P. 2010; Kröber, M. et al. 2008). To identify biomass yield of a Short Rotation Coppice, operators are very interested in methods which are easy to handle, efficient and sufficient in accuracy. Appropriate techniques can reduce the lack of knowledge according to biomass yield in Short Rotation Coppices. Beside high requirements in accuracy and functionality the destruction of stand biomass during measuring procedures has to be reduced to lowest level. Science and SRC operators aim at the same target, therefore results gained in this project are relevant to scientists as well as practitioners across regions of validity.

Comparison of estimation techniques

Since biomass yield of SRC plays a crucial role for an economical cultivation, many researchers in Europe have been focusing on exact measuring and estimating of stand biomass (e.g. Nordh, N.E.; Verwijst, T.; Telenius, B.; Röhle, H.). Apart from biomass measurements and estimations, predictive models were developed to better identify biomass yield of SRC. Hence several techniques, which differ in required input parameters, work intensity and accuracy, are available. A comparison of several estimation techniques assisted to choose the most appropriate technique for this research project. An overview on tested techniques and procedures is given further below.
In general two major types of biomass estimation can be distinguished as shown below in Table 1.

Table 1. Overview of different yield estimating techniques

Type 1: destructive techniques	Type 2: non-destructive techniques
1. Partial harvest methods 2. Complete harvest method ● high amount of work ● expensive ● destructive ● accuracy depends on sample unit	1. Biomass estimation based on ● Statistic empirical models ● Process based ecophysiological models ● less amount of work ● cheap ● non-destructive ● accuracy depends on model validity

In the range between destructive and non-destructive techniques further techniques can be found which are “semi-destructive”. Several parameters have to be measured at some sample trees. The sample data are projected on the whole stand subsequently. Most of them are based on regression analysis (Hartmann, K.U. 2010; Röhle, H. 2009; Verwijst, T., Telenius, B 1999; Hytönen et al. 1987).

Procedure No. 1: Biomass estimation by the help of regression methods:

The basic principle of biomass estimation through the application of regression methods is establishing a connection between weight of stem and one further factor, which is easy to measure and equating them by using a regression analysis. Through this procedure biomass of single trees and stand biomass [tons per ha] can be generated. Many authors have confirmed the relation between stem diameter at 1,3 m in height (DBH) and stem weight. The definition of a biomass function consisting of only a few input parameters is therefore possible and efficient. Including height in the independent variable (higher workload) does not contribute to better results (Hartmann, K.U. 2010; Röhle, H. et al. 2006; Ballard et al. 2000; Verwijst, T, Telenius, B. 1999):

$$BM = a_0 * d_{1,3}^{a1} \qquad (1)$$

BM: stem weight ; $d_{1,3}$: diameter at breast height (DBH); a_0, a_1: regression coefficients

For biomass estimation the DBH of all stems or a sample has to be measured by chop and harvesting a sample of stems is required:

To build wood diameter classes 250 to 300 DBH were measured on a representative area. In the following step 25 trees were taken as sample on the basis of the diameter distribution and subjected each tree to the measurement of following parameters:

- **DBH**
- **Weight**

Additionally: **Shoots per stool, failure rate** and **stand area size** have to be measured.

In order to determine water content three sample pieces of each stem were taken. One taken at 0,5 m in height, one at the middle of the stem and one at the absolute height minus 0,5 m and mixed them as composite sample per stem. All samples were dried at 104∞C for about two days to gain constant weight after weighing. The difference of weight before and after drying represented the amount of pure water. In the following step dry-matter of each stem was calculated and a site-specific biomass function was created by courtesy of regression analysis. Through the application of the generated biomass function the dry-matter of the 250-300 stems was calculated only on the basis of DBH measurement. The arithmetic mean of their weight is the average weight of the average stands stem. The product of shoots per hectare multiplied with average weight of the average stem generates finally biomass per hectare.

The advantage of this method is a adoptable function for computing stand biomass, which is exactly fitting for site, clone and age. There is “no statistic significant difference [between real stem weight and stem weight calculated by regression method]” (Röhle, H. 2009 p. 225). Other scientists proved a maximum difference of 7 % (Nordh, N.E., Verwijst, T. 2004).

Procedure No. 2: Biomass estimation with quadratic mean diameter (d_g):

Quadratic mean diameter is an important figure in forest mensuration. The quadratic mean diameter is equal to tree/stem which represents average basal area. Because basal area is correlated to stems biomass, it seems to be possible to deduce stands biomass by quadratic mean diameter (QMD) (Prodan, M. 1965). After measuring DBH of sample of 250-300 stems -distributed over stands area- QMD was calculated by using the following formula:

$$d_g = 2 * \sqrt{\frac{\frac{\sum_{i=1}^{n}(\frac{\pi}{4} * d_i^2)}{n}}{\pi}}$$

d_g: quadratic mean diameter; d_i^2:diameter at 1,3m (DBH); n: number of stems per sample unit

To run the entire process based on quadratic mean parameter one stems with d_g was weighed and samples for water content taken as stated above. First it was checked if one of the 25 sample stems used for regression method is according d_g. The average dry weight was multiplied with real number of stems/shoots per hectare to get the stand biomass.

Procedure No. 3: Biomass estimation by using yield estimation model created by Technische Universität Dresden (Germany):

The third estimation technique is a non-destructive SRC biomass yielder created by Röhle, H; Hartmann, K.-U.; Skibbe, K; Schlotte, M, based on dissertation of Hartmann, K.-U. It is a user friendly software, estimation SRC yield for commercial purpose (easy handling and as accurately as possible). As every biomass estimating method, it is a compromise between time demand for data collection and accuracy of the result. Hartmann, K.U. states an average bias of 7%, maximum aviation of +-40% and root mean square R^2 0,95. There is a relative high inaccuracy in using this procedure for biomass estimation. However the technique seems to adequate for commercial purposes, SRC operators who want to assess their actual yield, particularly as only little numbers of DBHs and additionally DBHs in combination with height of 25 sample trees have to be captured. A valid application can be only achieved for sites, which parameters lie within in the following range (Hartmann, K.-U. 2010):

Altitude above sea level:	120 - 650 m
Annual precipitation:	450 – 1300 mm
Annual mean temperature:	7 - 10 ∞C
Soil Quality Index (SQI):	30 – 70
Age:	3 - 10 years
Number of stems:	1000 – 25000/ha
Average stem height:	3 – 16m

Almost all investigated SRCs lie within the given range, except all sites established in 2009 were excluded from validation of procedure No. 3. To apply the biomass estimation software, *planting determinate*, *area size*, *drop-out rate* and *sampling error* are required. In order to prevent small scale site differences falsifying the comparison of methods, DBHs and height of trees used for procedure No. 1 were taken again for this method. In the following a sampling design is calculated: Measuring DBHs of 81 stools - including size, drop-out rate and shoots per stool of this sample unit are automatically integrated in the number of DBHs entered to the software. Therefore it is essential to enter the right number of DBHs. Therefore calculated sample size was multiplied with number shoots per stool less failure rate. Finally, the number of random chosen DBHs and 25 DBHs and heights were entered.

In order to compare the three procedures and thereby determining their quality, procedure No. 1 is set as reference level, since its error rate is stated to be the lowest and furthermore it can be verified stand-specifically. The stand biomass ascertained by regression analysis is equated to 100%. The deviation of the other procedures is calculated as relative deviation in percent.

Finally it has to be mentioned again, four of the total number of 14 sites were established only two years ago and therefore these sites are out of the range of given parameters in procedure No. 3. However data were collected for these sites anyway, that data were included for tests but not for model validation. This has to be kept in mind, when considering next figures.

Results

The key results of the three procedures are summarized below. For all sites the year of establishment is given.

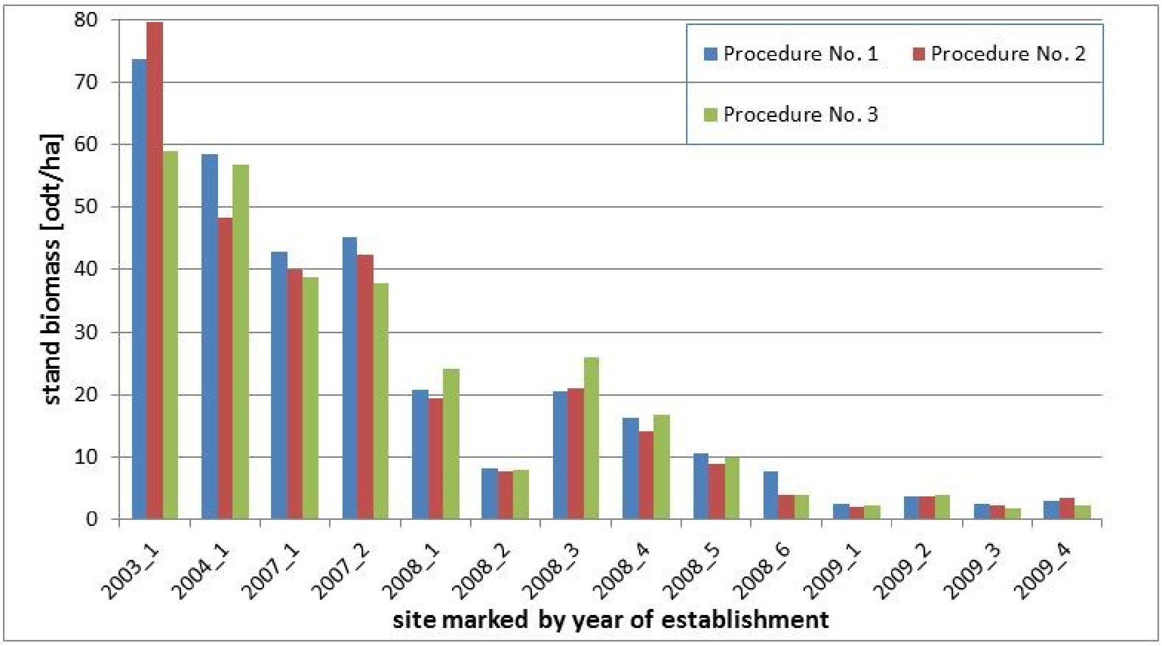

Fig.2: Estimated stand biomass

Following Figure 2 it seems that the final results of estimated stand biomass of all three procedures do not vary significantly. To gain a better impression on differences and validation of the investigated procedures, deviation of the procedures in comparison to procedure No. 1 is given below in Figure 3.

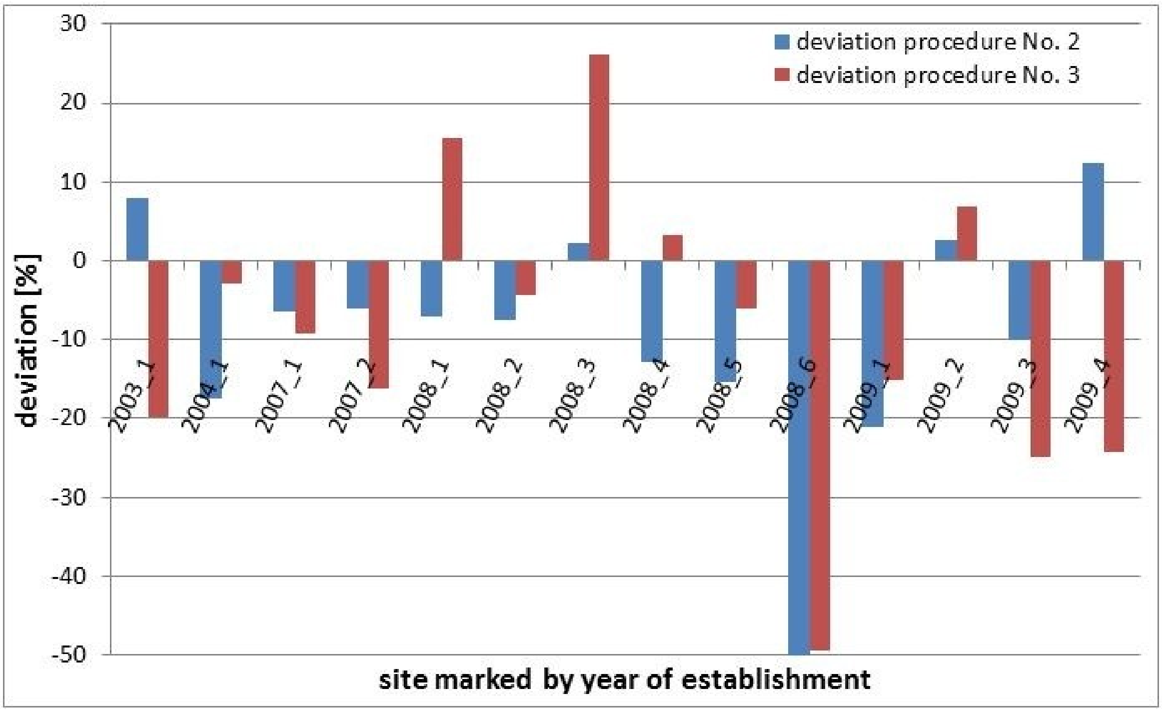

Fig.3: Deviation of the procedures

A positive and negative deviation can be observed at both procedures, but in total there is a clear trend towards negative deviation for procedure No. 2 and No. 3 as shown in Figure 3. This visual impression is strengthened by descriptive statistical parameters, in this case arithmetic mean and median of deviation (compare Table 2). For both procedures a negative arithmetic mean and negative median of deviation can be observed, which means both procedures underestimate the results calculated with procedure No. 1 which is equated to 100% and consequently regarded as realistic value.

Looking at Figure 3 several matters attract attention: First it seems procedure No.2 has a smaller deviation than procedure No.3. Second: Sites established 2009 has been estimated in comparatively acceptable quality by procedure No. 3 even if it is not parametrized for two year old stands; furthermore the 4 sites established in 2009 are the sites with slowest and smallest growth, so even higher deviation was expected.

Third point attracting attention is: The rectified deviation of site „2008_6“. That leads to the impression, biomass estimation with regression analysis is not accurate enough. For testing it, two sided, paired t-tests were carried out, to compare all real weights and weights calculated per regressions analysis. The result shows, that there is no statistically significant difference between real and calculated weight. Consequently stand biomass calculated with procedure No. 1 is accurate and the strong deviation for the sites 2008_6 must have other reasons. To give a visual impression of that, Figure 4 shows differences between real and calculated weight per regressions analysis of site “2008_6”, the differences at all other sites are even smaller.

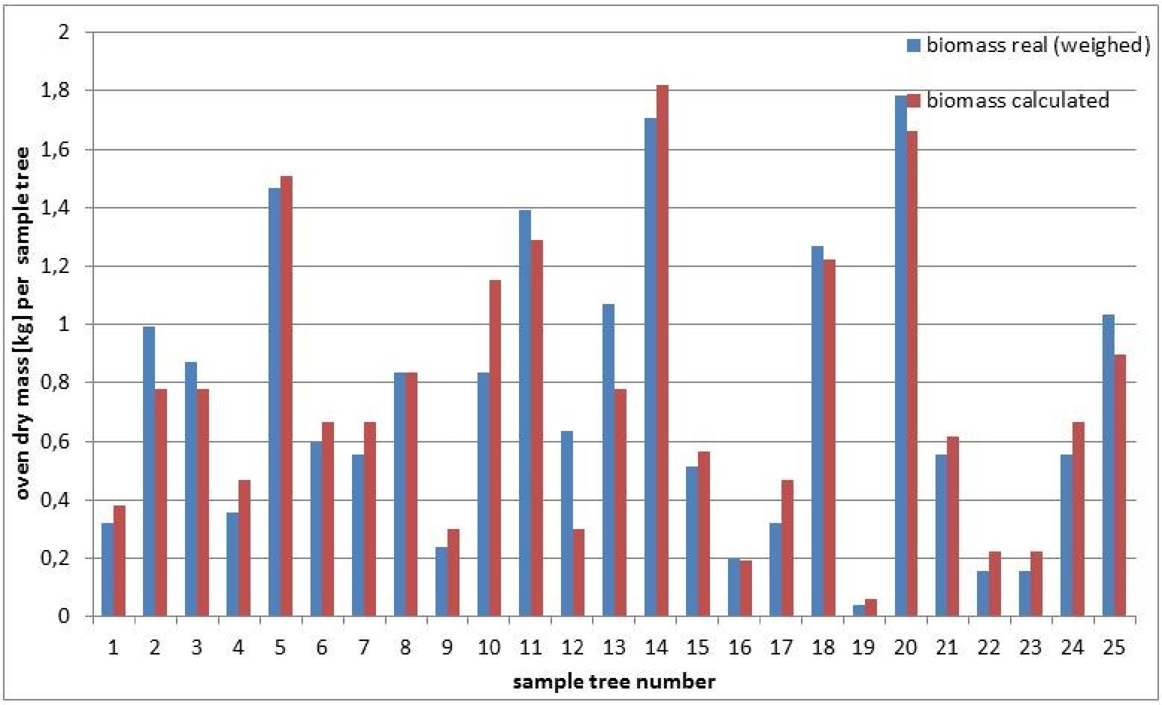

Fig.4: Comparison of real stem weights and calculated stem weights of 25 sample trees [kg – oven dry]

After the accuracy of procedure No.1 has been approved, the question raises, which of the remaining procedures are more appropriate than the other? Due to time constraints and the aspect of high labour intensity, procedure No. 1 is not appropriate for application in this research project. A more time saving and less labour intensive biomass estimation technique needs to be chosen.

Only procedure No. 1 or No. 2 allows to measure different sites within a reasonable amount of time.

Table 2. Descriptive statistical parameters of deviation of procedures

	arithmetic mean	median	standard deviation	variance	max	Mi
Procedure No. 2	-11,31	-7,35	15,73	247,54	7,97	-50,44
Procedure No. 3	-6,28	-5,18	20,49	420,02	26,20	-49,35
Procedure No. 2 *	-6,96	-7,17	8,11	65,83	7,97	-17,51
Procedure No. 3 *	-1,50	-4,36	14,66	214,89	26,20	-19,88

* Descriptive statistical parameters except outlier “2008_6”; max, min: Maximum/minimum deviation [%]

Table 2 shows descriptive statistical parameters of deviation of procedures in comparison to procedure No. 1 in percent. Both arithmetic mean as well as median of procedure No. 3 shows less deviation than procedure No. 2. Standard deviation and variance, which are indicators for distribution, however, is much lower for procedure No. 2 than for procedure No.3. The range between minimum and maximum supports that aspect. Hence, procedure No. 2 is the one with the higher accuracy even if arithmetic deviation is less exact, than procedure No. 3. Consequently procedure No. 2 is more approriate for investigated purposes. This conclusion can be drawn only under limitations and depending on the point of view and the field of application.
Procedure No.3 has got higher variance and deviation is scattering stronger than deviation of procedure No. 2. That means, estimating biomass with procedure No. 3 will deliver results, which tend to feature a high deviation in comparison to real stand biomass. Therefore procedure No. 2 is more suitable, when an exact measurement of stand biomass is required. For SRC operators with only a single SRC this biomass estimation technique might deliver best results, when focus is on accurate stand biomass as mentioned before.

However, when the average stand biomass is of interest for the SRC operator, procedure No. 3 should be chosen. For example when an SRC operator has a great number of areas of SRC and the amount of average standing biomass is required.

The accuracy of procedure No. 1 was confirmed, hence this reason for large deviation of stand biomass “2008_6” can be excluded. Site “2008_6” shows the highest range of DBHs, which can be traced back on small scale site differences. A definite answer has not been identified yet and more intense needs to be done at this point of large deviation. Therefore results „2008_6“ has to be treated as outlier and are not concerned for model validation in further steps; results shown on Table 2 are marked with “ * ”. The trend mentioned before even gets clearer, where standard deviation of procedure No. 2 is halved, but deviation of procedure No. 3 is still three quarters. The accuracy of procedure No. 2 gets relatively more exact after outliers exclusion.

Most of the results of No. 2 match with given validity by Hartmann, K. U. After excluding the outlier of site “2008_6” the results of procedure No. 2 are completely within range of validity, Hartmann K.U. 2010 indicated:

- Average bias: 7%
- Maximum relative deviation is less +-40 %

“No systematical over-/underestimation can be observed” (Hartmann, K.U. 2010). This is not exactly valid, because results generated through procedure No. 3 underestimates the real biomass.

Because differences of the results calculated with procedure No. 2 and procedure No. 3 are not that big - by contrast with the accuracy of procedure No. 1 - another factor for method validating has to be added: Amount of work. For using procedure No. 3 just a few input parameters are required: A certain number of DBHs (as calculated by software) and 25 DBHs and 25 heights of 25 sample trees. Whereas for procedure No. 2 some more input parameters/work stages are required: Calculating d_g

(quadratic mean diameter), searching, harvesting, weighing and generating water content of a sample tree with DBH = d_g.

Workload of procedure No. 2 is significant higher than workload of procedure No. 3, which results in higher financial expenditures finally. More work stages have to be passed through and more measuring tools are required. At his point the question raises, where to shift priorities in decision. It is questionable whether the higher degree of accuracy is worth to be paid with a significant overhead.

Finally to apply procedure No. 2, some further aspects need to be clarified. As described, estimation stands biomass is based on projecting biomass of one stem to whole stands biomass. It is relatively likely, that one chosen sample tree where DBH = d_g, data gained will not be exactly representative for quadratic mean diameters weight. This error is multiplied with the number of stems per hectare, which are about 5000 – 10000 stems at investigated sites. For instance the deviation of one sample stem of 50g multiplied with 10000 stems per hectare will result in 0,5 odt/ha deviation of stands biomass. The risk of such an error can be reduced when more sample trees are withdrawn.

The above procedure follows the assumption that the application of biomass estimation procedure on the basis of quadratic mean diameter with a greater number of sample trees, approximately up to three or five, will even bring significant improvements of biomass estimation accuracy. The additional amount of work increases only on a small scale. If this assumption is confirmed, biomass estimation of SRC by procedure No. 2 would be the most appropriate biomass estimation technique. To approve or disprove this assumption further investigations have to deliver reliable results.

Conclusion

Three different biomass estimation techniques, with various requirements in labour intensity and input parameters as well as different accuracy, have been tested. 14 sites of Short Rotation Coppice, all of first rotation period, were defined and investigated during this research project. The aim of this study was to identify a biomass estimation technique which is fast in application and delivers accurate results as the purpose requires. Biomass estimation with site specific biomass function on the basis of regression analysis was validated as procedure with highest accuracy. For SRC operators which are in need of high accuracy in biomass estimation are recommended to apply technique of procedure No. 1. The workload, including the harvest of 25 sample trees, is on a reasonable scale for this purpose and quality of result.

For the purpose of the research project sufficient time for the intensive estimation technique on the basis of regression analysis is not given. Furthermore the harvest of 25 trees at every single site is not desirable from the view of the operators. It is required to accept a certain reduction of accuracy in order to profit from the advantage of a faster application to meet the optimum in the purpose of the project. Consequently focus has to be shifted to procedures No. 2 and No. 3, the one based on quadratic mean diameter and the other on the estimation software. Procedure No. 2 is rated better in terms of precision calculating individual stand biomass but only at the expense of a higher overhead in comparison to procedure No. 3. Another first assumption can be formulated that an increasing number of sample trees for procedure No. 2 affects the accuracy significantly. However this assumption has to be clarified in further investigations.

Estimation with procedure No. 3 results in individual stand biomass with less precision than procedure No. 2, however in total these differences get almost compensated. This fact is interesting for operators of biomass estimation who have a great number of SRCs and are only interested in the total amount of their sites biomasses. As a consequence absolute evaluation is not possible. Biomass estimation procedure has to be chosen according to the required purpose of the SRC operator.

In summary it can be stated, both procedures No. 2 and No. 3 are practical for commercial purposes, as far as the established (in)accuracy is adequate to operators requirements.

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Potential of biofuels sources in Indonesia: Policy initiatives

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1. Introduction

The growing national and International demand of bioenergy can cause shortage of fossil fuels. On the other hand, energy utilization is always linked to the emission generation. Fossil energy sources are the major contributors to greenhouse gases (GHGs) emission and climate change, 60% of GHGs emission come from fossil energy utilization. In order to minimize the global warming as a result of the increase of GHGs emission, the replacement of petrol chemical products to bioenergy is a must. Since almost all bioenergy can be traced back to energy from sunlight, bioenergy has the major advantage of being a renewable energy sources.

Moreover, Indonesia has a comparative advantage for bioenergy production because of greater availability of land, favorable climatic conditions for agriculture and lower labour cost. However, Indonesia faces socio-economic and environmental implications affecting the potential to benefit from the increased local and global demand of bioenergy. The Interrelationship between land uses and the competing needs of energy and food security is a key issue that should be considered. Such kind issues directed the Goverment of Indonesia to make regulation for bioenergy development. Biofuel is a kind of bioenergy, a wide range of fuels which are in some way derived from biomass and need to develop.

There are main reasons why we should use and develop biofuel. For developed countries is for greenhouse (CO_2) gas emission abatement, while for developing countries as energy security, Improving balance of payment, jobs creation, poverty alleviation, and domestic market utilization.
Indonesia has vision and mission on developing biofuel, the vision is to reduce poverty alleviation, to increse employment creation through development of biofuel as alternative energy, to increase people‘s welfare, while the mission are: to create employment opportunities (feedstock supply, industry, infrastructure, and supporting ivities), to increase rural community independency, to increase the role of private sector involvement, To regulate biofuel business, to supply feedstock and utilization, and to develop business climate through incentives.

This paper aim to explore deeper potential biofuels in Indonesia, because Indonesia have a lot of potential biofuels to develop. The feedstock for bio-oil and biodiesel production has been planned mainly from palm oil and *jathropha curcas*. How ever, other potential feedstock such as unused frying oil, rubber seed, neem, etc are also encouraged. *Calophyllum inophyllum* is one of potential biofuel that it is prospected to develop because it has some strong points.This species is being studied at Forest Research Development Agency, Ministry of Forestry- Republic of Indonesia.

2. Policy and program of bioenergy in Indonesia

2.1 Bioenergy and biofuel

Bioenergy is energy contained in living or recently living biological organisms, a definition which specifically excludes fossil fuels. Plants get bioenergy through photosynthesis, and animals get it by consuming plants. Organic material containing bioenergy is known as biomass. Humans can use this biomass in many different ways through something as simple as burning wood for heat, or as complex as genetically modifying bacteria to create cellulosic ethanol. Since almost all bioenergy can be traced back to energy from sunlight, bioenergy has the major advantage of being a renewable energy source. Indonesia has planned to develop renewable energy from various source to fulfill domestic need of energy. Planning development of renewable energy from different sources as shown at Table 1.

Biofuel includes wide range of fuels liquid biofuels (bioethanol, biodiesel, and other liquid biofuels), solid biomass (wood, biomass pellet, charcoal), and various biogases (biogas, biopropane) which are in some way derived from biomass. Bioethanol could be produced easily from sugar contained crops such as sugar cane, sago, corn, and cassava. The requirement of fuel grade ethanol on the national basis is estimated at 420 million liters per year. Bioethanol consumption (2006-2010) is depicted in Table 2.

Table 1. Planning Development of Renewable Energy in Indonesia

Energy source	Unit	2007	2010	2015	2020	2025	potency
Biodiesel	Kilo litre	133	482.000	1.700.000	5.784.000	14.819.000	No data
Bioetanol	Kilo litre	-	296.000	1.112.000	3.624.000	9.106.000	No data
Pure plant oil	Kilo liter	-	208.000	1.016.000	2.644.000	5.901.500	No data
Another biomass	MW	445	500	590	710	870	49810
Geothermal	MW	1.052	1260	4156	7788	12232	28000
Wind	MW	2	4	40	128	256	8290
Sun	MW	12	25	75	324	580	4.8 Kwh/ m^2/day
Mikro hidro	MW	210	245	417	760	1425	No data
Makro hidro	MW	4200	4380	6069	8940	10940	76.170

Source: Blueprint EBTKE planning 2010

Table 2. Prediction of bioethanol consumption (2006-2010)

	Year	Bioethanol consumption (millions kl)
2	2006	1.71
3	2007	1.75
4	2008	1.78
5	2009	1.82
6	2010	1.85

Source: Prihandana *et al*., 2007

The feedstock of bioethanol in Indonesia is planned mainly from sugarcane and cassava. However, it was found that other sources potential as bioethanol feedstock in Indonesia (Table 3.)

Table 3. Potential sources of bioethanol feedstock

Source of Feedstock	Yield	Ethanol (l/ha/year)
Corn	1 – 6 Ton/Ha/year	400 – 2500
Cassava	10 – 50 Ton/Ha/year	2000 - 7000
Sugarcane	40 – 120 Ton/Ha/year	3000 – 8500
Sweet potato	10 – 40 Ton/Ha/year	1200 - 5000
Sorghum	2 – 12 Ton/Ha/year	1500 - 5000
Sweet Sorghum	20 – 60 Ton/Ha/year	2000 – 6000
Arrenga Pinnata	0.6 – 1.2 million liter/ha year	40000 liter/hayear
Molasses	2000 liter/ha/year	500 liter/ha/year

Source: Prihandana *et al*., 2007

It is important to notice that *Arrenga pinnata* has the highest production of ethanol. However, the ecosystem of this plant is limited. Sugarcane and cassava is the second and the third highest ethanol production respectively. Even though both feedstock are also used for food, the extension area for plantation are still wide. Therefore, government focuses on the development of sugarcane and cassava as the feed stock. Sweet sorghum may be another potential feedstock of bioethanol in the future.

Waste of food crops also potential for energy source such as [paddy (rice straw and hull); maize (stem, leaves, hairs, and fruit core); cassava (stem, leaves); peanut (stem, leaves, and fruit shell); and soybean (stem, leaves, and fruit shell)]. Table 4 shows the estimation potency of food crops waste.

Table 4. Harvesting area, productions and waste potency of some food crop products

No	Agricultural products	Harvesting area (10^3 ha)	Production (10^3 ton)	Yield rate (quintal/ha)	Conversion factor (ton/ha)	Potency (10^6 ton)
1	Paddy	**11.786.430**	54.454.937	46.20	5.1	**60.110**
2	Maize	3.345.805	11.609.463	34.70	5.2	17.398
3	Cassava	1.227.459	19.986.640	163.00	6.1	7.487
4	Peanuts	706.753	838.096	11.86	2.0	1.413
5	Soybeans	580.534	747.611	12.88	1.8	1.045
	Total					87.453

Source: (Sudradjad, 2004; MOA, 2006)

Bioenergy production may also cause harmful environmental effect such as deforestation and loss of biodiversity. One of the barriers in developing renewable energy technology and clean energy technology is related to its high investment cost because, most of the technologies are still imported. Therefore, research and development activities to produce local proven technology with lower down the cost.

2.2 National policy on bioenergy

The Minister of Energy and Mineral Resourc issued a National Energy Management Blueprint (NEMB) to support the National Energy Policy (NEP). Presidential Regulation No. 5/2006 implements the NEMB states the purpose of the National Energy Policy to ensure a secure domestic energy supply and to encourage sustainable development. Article 2 establishes a target for biofuels to contribute at least 5 per cent of the total energy consumption by 2025. Presidential Instruction No. I/2006 establishes the framework for coordination among ministries to promote the supply and the use of biofuels. It designates ministries responsible for formulating and implementing policies, including incentives, tariffs and trading system, as well as standard and procedure for cultivation methods, processing, quality testing, the supply and distribution of biofuels, the provision of land and the development of research and technology.

Specific to agricultural production, articles 3 and 4 provide that Ministry of Agriculture shall encourage the provision and development of biofuels plants including seeds and seedlings, whereas the Ministry of Forestry shall provide licences regulating the use of unproductive lands for biofuel plantations. Indonesia established biodiesel standard SNI 04-7182-2006, which was approved by the National Standardization Agency under on 22 February 2006. The biodiesel standard was formulated by taking into account similar standards already applied in other countries such as ASTM D6751 in the US and EN14214:2002 in the EU. The Oil and Gas Directorate General of the department of Energy and Mineral Resources issued a decree regarding the quality and specification of two types of diesel oil. This decree regulates the use of fatty acid methyl ester up to maximum of 10 percent of the volume of automotive diesel fuel with which it is to be blended. The biodiesel to be mixed has to meet the biodiesel standard SNI 04-7182-2006.

As a response to the government‘s seriousness in supporting the biofuel development as a national priority program, a number of research institutions such as Bogor Agricultural University, BPPT Biotechnology Centre, Centre for Plantation Forest Research and Development, Ministry of Forestry, Ministry of Agriculture, several private and state companies such as PT. Energi Alternatif Indonesia, P.T. Rekayasa Industries, P.T. Eterindo Wahanatama, P.T. Rajawali Nusantara Indonesia have started actively on biodiesel business.

2.3 Village self-sufficiency energy program

Indonesia has many villages scattered in various island. The villages are usually isolated to accessibility. Most of them have minimum access to road, education, health, electricity, and distribution of fuel oil. These isolated area are usually categorized below the poverty line. We can see in Papua, the price of household kerosene is 2 US $ per litre, while the highest allowable price for subsidized kerosane is 0.4 US $ per litre. To overcome this problem Government of Indonesia has developed a self sufficiency energy program (SSEP). This program is a participatory rural approach program.

The Self sufficiency energy program is developed by the networking system of a nucleus and several plasmas. The nucleus could be the processing plant in a village scale while the plasma consist of farmers group who produce the feedstock. Making it sustainable, it should be proceeded by the feasibility assessment on technical, and socio-economic basis, assessment, evaluates relation between the agro-ecosystem and socio-economic feasibility. Potential commodities based on SSEP areas palm oil (*Elaeis guineensis*), *Jatropha curcas*, cassava, sugar cane, sorghum, corn, sorghum, *Arenga pinnata*, and *Calophyllum inophyllum*.

Self sufficiency energy program (SSEP) or special region foe biofuel development is one of program to open job opportunity and reduce poverty of people at isolated area by empowering the society to fulfil their energy needs. This program can exploit 5 million hectares marginal land to produce several kinds of biofuel feedstock, and it can create job opportunity for 3-5 million people.

3. Potential biofuel in Indonesia

There are some potential biofuels in Indonesia such as: *Elaeis guineensis* (palm oil), *Jatropha curcas L (Jarak Pagar), Pongamia pinnata (pongam, malapari), Azadirachta indica (*Neem, Nimba*), Ceiba petandra (*kapook*), Hevea brasiliensis (*rubber tree*), Calophyllum innophyllum* (ballnut*)*. In this paper, *Calophyllum inophyllum* (nyamplung)*,* is one of potential biofuels being researched at Forest Research Development Agency, Ministry of Forestry Republic of Indonesia, has been elaborately explained for its potential and adoption in Indonesia.

3.1 *Callophyllum inophyllum*

Callophyllum inophyllum L (family *Clusiaceae*) is a coastal tree, distributed all over the world: [Madagascar, Malaysia (bintangor), Indonesia (nyamplung), East Africa, Pacific Islands, West Indies (poon), and South America]. In Indonesia, is found in west coast of Sumatera, Java, West Kalimantan, Sulawesi to Papua province. According to International Union on Conservation Nation (IUCN), it's one of endangered species in Indonesia. This species has multifunction benefits, both its wood and fruits are used. Species helps in forest and land rehabilitation, wind-breaker, medicine, alternate biofuel, and wood (boats, beam, pillar, floor roads).

Now a days it is widely cultivated in all tropical regions of the world, including several Pacific Islands. Because of its decorative leaves, fragrant flowers and spreading crown, it is best known as an ornamental plant. This tree often grows in coastal regions as well as nearby lowland forests. However it has also been cultivated successfully in inland areas at moderate altitudes. It tolerates varied kinds of soil, coastal sand, clay or even degraded soil. It usually reaches 8 to 20 metres in height. The flower is 25 millimetres wide and occurs in racemose or paniculate inflorescences consisting of 4 to 15 flowers. Flowering can occur year-round. The fruit (the ballnut) is a round, green drupe reaching 2 to 4 centimetres in diameter and having a single large seed (Fig. 1). When ripe, the fruit is wrinkled and its colour varies from yellow to brownish-red.

Forestry of ministry Republic of Indonesia ha provided three million nyamplung seed *(Callophyllum inophyllum).* Seeds to be planted in 3000 ha of idle land along the country's coastal area. Cilacap Regency had planted 148.222 *Callophyllum inophyllum* seeds at 350 hectares in coastal areas in 2007. Minimal production per tree per year is 50 kilogram, and one kilogram of dried nyamplung can produce 0.4 liters of oil. Total area in Indonesia that are planted with this species is about 480.700 ha. This source of biofuel could be better than edible biodiesel sources, such oil palm. A team of local farmers had tested and used nyamplung oil as fuel. Cultivation of this species still in the beginning, so it is estimated for the five year next, the production can only be harvested from natural forest. It is estimated that if 10 per cent from total natural forest (5.000.000 ha) is *Callophyllum inophyllum stand* (50.000 ha). Minimal production per ha per year is about 10 ton, so it's predicted that total production is about 500.000 ton per year.

There are several reasons in favour of the species become significant source of future biofuel (FORDA, 2009):

1. It is spread over widely along coast in Indonesia from Sumatera to Papua
2. Easy to cultivate either in monoculture way or in mixed forest
3. Productivity of *Calophyllum iniphyllum* seed is higher (20 ton/ha) than *Jathropha curcas* (5 ton/ha), and oil palm (6 ton/ha)
4. It has high seed rendemen (74%) compare to palm oil (46-54%), *Jathropha curcas* (40-60%)
5. It can Produce fruits along the years
6. It has high survival rate.
7. All parts of *Calophyllum inophyllum* tree can be used for commercial products
8. It stand can be applied as windbreaker, as coast conservation
9. It has no impact on food supply

10. This species has double power burning compare to kerosene. It has been tested to boil water needs only 0.4 ml of callophyllum oil compare to 0.9 ml kerosene

It had been tested on the road (road rally test) three times, total distances reaches 370 km. It results satisfactory without any disturb technical engine, and Vehicle speed is about 129 km/hour. The engine test got certification from National Board of Certification. Unfortunately, it hasn't been produced in large scale industry, it is still in laboratory scale. According to the description above *Callophyllum inophyllum* is very potential to develop as biofuels resource.

Fig. 1: *Calophyllum inophyllum*

4. Conclusion

- There is lot of potential for biofuel development using several commodities as feedstock in Indonesia, and land availability are abundant for biofuel development without converting natural forest areas to cultivable land

- Government of Indonesia is supporting biofuel development program, as one of alternative energy with regulations, policies, and dissemination.

- Village self-sufficiency energy program (VSSEP*)* is a program of special region for biofuel development to open job opportunity and eliminate poverty at isolated or remote villages by empowering the society to fulfil their energy needs

- Feedstock from palm is ready to be used for biodiesel domestically, but it competes with cooking oil, while *Jathropha curcas*and other non-edible oils are still at its initial stage of development. *Callophyllum inophyllum* is one of forest product that has potential to be developed as biofuels.

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Mapping of land suitability for oil plam under different land system in Indonesia.

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1. Introduction

The increasing human population, the more consequent accelerating demands and intensity of human activities on the land have various degrees of impact on all of the material and natural resources in the world. Human population pressures have accelerated the land value and the diversity of land use. Land is becoming scarce so that the more fragile upland areas are looked upon as the last frontier for the expansion of agriculture and other land uses. As a result, numerous problems have now been threatening the ecological stability of much upland.

At the moment, there is a trend to make use of the land for the economic interests, which could increase the income. One of the favourite and high-economic-value plants in Besitang watershed, Indonesia is oil palm. The land conversion to oil palm plantation and fish pond in the mangrove forests by the surrounding community have decreased the size of the available area in the watershed area. Land as resource cannot be measured by the surface area alone; hence the types of soil which is critical for productivity, underlying geology, topography, hydrology, and plants/animal population also has to be considered (Ekanayake and Dayawansa, 2003). These attributes limit the extent of land available for various purposes. The growing population, industrialization and misuse and overexploitation of land resources have in effect increased the demand for land.

Changes in land use at various spatial and temporal levels can have either beneficial or detrimental effects. The latter is the main concern of decision-makers because of its effect on the population and the environment. The goal of managing land use and its change is to develop the land resources in ways that capitalize on the local potential and suitability, avoid negative impacts and respond to present and future societal demand within the limits of the carrying capacity of the natural environment (FAO, 1995).

Based on the Besitang watershed condition, some good steps or actions are needed to overcome these problems. Rehabilitation of watersheds is also needed so that it can support and enhance other environment functions. The mapping of land suitability has never been conducted previously in the area, therefore, it is essential that research in this area be conducted. This study aimed to assess and map land suitability for oil palm under different land systems in Besitang watershed, Indonesia.

2. Material and methods

2.1. Description of the study area

The study was conducted in the Besitang watershed, from April to August 2008. Administratively, the study area lies in the Langkat Regency, North Sumatra Province, Indonesia. It consists of five sub-districts, namely: Besitang, Barandan Barat, Padang Tualang, Pangkalan Susu, and Sei Lepan.

Besitang watershed has an area of 100,035 ha excluding the islands. In the border of Malaka Strait in the East, there are islands that have an area of 5,089 ha. Geographically, it is located between 97° 50' to 98° 20' East longitude and 03° 45' to 04° 15' 20" North latitude. It is bordered by the Province of Nangroe Aceh Darussalam in the North, Sei Lepan watershed in the South, Malaka Strait in the East, and the Province of Nangroe Aceh Darussalam in the West.

2.2. Data collection

Primary data was collected through a field survey. Ground survey was conducted to gather physical data (soil) and rainfall station point from the watershed area. To gather the soil data, the area was divided into three sub-watersheds and 12 decision zones (DZ). The upland stream sub-watershed was divided by four decision zones (DZ 1 to DZ 4), the middle stream sub-watershed was divided into three decision zones (DZ 5 to DZ 7), and lower stream sub-watershed was divided into five decision zones (DZ 8 to DZ 12). The decision zones are sites of more or less common features, that is, homogenous regions. This not only facilitates the analysis procedure, but also allows the decision-maker to make well informed assessments regarding the area (Bantayan, 1996). The decision zones were identified using land systems. The basic concept of land system is to divide the landscape into area meaningful for development planning. The land concept is based on ecological principles and presumes closely interdependent links between rock types, hydroclimatology, land form, soils and organisms. The same land system is recognized wherever the same combination of such ecological or environmental factors occurs. A land system therefore, is not unique to one locality only, but in all areas having the same environmental properties.

In this study, soil samples were taken from the area based on land system/decision zone. The fifteen soil samples were analyzed to get physical characteristics. They include slope, flood hazard, soil dept, temperature, texture, cation exchangeable capacity (CEC), saturation, pH (H_2O) and Na-exchange.

Ground survey was conducted to gather rainfall station point from the watershed area to generalizing the stations over the study area by creating Thiessen polygon in ArcView GIS. Of the six rainfall stations point that were obtained as representative points, only four were used as representative points, namely: Besitang, Pangkalan Susu, Brandan Barat and Batang Serangan Station. The secondary rainfall data 1996-2006 was retrieved from the Meteorological and Geophysical Agency Regional I Sampali, Medan, North Sumatra. They were used to derive the rainfall erosivity factor (R). Erosivity Map (R) was obtained from rainfall stations point survey and monthly rainfall data. Generalizing the stations over the study area was done by creating Thiessen polygons in ArcView GIS. The rainfall emissivity factor (R) was calculated using Lanvine Formula (Ministry of Forestry, 2005).

Secondary data were gathered from different offices. Soil depth in Besitang Watershed was obtained from the Ministry of Forestry (2005). Other information that were collected, such as: explanatory booklet of the land unit and soil map of the Medan sheet (0619) Sumatra (1990), the field technique planning for Land Rehabilitation and Soil Conservation in Besitang Watershed (2005), Main Report (Review of Phase I Result, Sumatra) of RePPProT (1988) Volume I and II, the Spatial Management Plan Related to Regional Land Uses in Langkat Regency (RTRWK) 2002-2011 and the Regional Langkat Government Regulation Number 03 (2006) about the Langkat Regency Development Planning (2006-2010) were obtained from Regional Development Planning Board of Langkat Regency (BAPPEDA).

2.3. Methodology

Land suitability classification (LSC) was evaluated based on matching method that reference and criteria was adopted from the Land Suitability for Agricultural Plants by the Centre for Soil and Agroclimate Research, Bogor (2003). The process of land suitability classification is the appraisal and grouping of specific areas of land in terms of their suitability for defined uses. The methodology adopted the land utilization type's concept which allows two orders of suitability, namely: suitability (S) and not suitability (N) and the three classes of the order suitability, namely: S1, S2, and S3, and two classes under not suitability, namely N1 and N2. The land suitability ratings have been defined by FAO (1976) for international use as follows:

Class S_1 : Highly suitable, land having no significant limitations to sustain application of a given use or only minor limitations that will not significantly raise inputs above and acceptable level.

Class S_2 : Moderately suitable, land having limitations that in aggregate are moderately severe for sustained application of given use. The limitation will reduce productivity or benefits and increase required inputs to the extent that the overall advantages to be gained from the use, although still attractive, will be appreciably inferior to that expected on class S1 land.

Class S_3 : Marginal suitable, lands having limitations, which are severe for sustained application of a given use and will so reduce productivity or benefits or increase required inputs that this expenditure will be only marginally justified.

Class N_1 : Currently not suitable, lands having limitations which may be surmountable in time but which cannot be corrected with existing knowledge at currently acceptable costs. The limitations are so severe as to preclude successful sustained use of the land type in a given manner.

Class N_2 : Permanently not suitable, lands having limitations which appear too severe as to preclude any possibility of successful sustained use of the land in a given manner.

This study also used one class under not suitable (N). The criteria of land suitability classification for oil palm based on The Centre for Soil and Agroclimate Research (2003) is shown in Table 1. For the purpose in this study, the actual and potential land suitability in the area was determined for oil palm.

Land suitability for oil palm mapping in the area was determined using ArcView GIS. The data gathered were encoded in the computer using the spreadsheet program (Microsoft Office Excel) and output tables were exported as data based file (dbf) table. Then, land suitability for oilpalm map was determined under different land systems (decision zones).

Table 1. Land characteristics and criteria for actual and potential suitability of the lands for oil palm (*Elaeis guinensis* JACK.)

Land characteristics	**Criteria for actual and potential suitability of the lands for oil palm**			
	S1	**S2**	**S3**	**N**
Temperature (tc) (°C)	25-28	22-25 28-32	20-22 32-35	< 20 > 35
Water availability (wa)				
Rainfall (mm/year)	1700-2500	1450-1700 2500-3500	1250-1450 3500-4000	< 1250 > 4000
Oxygen availability (oa) Drainage	well drained, medium	moderately poorly drained	poorly drained, moderately excessively drained	Very poorly drained, excessively drained
Root media (rc)				
Texture	Fine- Moderately Fine, Medium	-	Moderately Coarse	Coarse
Soil depth (cm)	> 100	75-100	50-75	< 50
Nutrient retention (nr)				
CEC (me/100g)	> 16	▪ 16	-	-
Base saturation (%)	> 20	▪ 20	-	-
pH H_2O	5.0-6.5	4.2-5.0 6.5-7.0	< 4.2 > 7.0	-

C-organic (%)	> 0.8	≤ 0.8	-	-
Sodisity (xn)				
Alkalinity/ESP (%)	-	-	-	-
Soil erosion (eh)				
Slope (%)	< 8	8-16	16-30	> 30
Soil erosion	Very low	Low-medium	High	Very high
Flood hazard (fh)				
Inundation	F0	F1	F2	> F2

Source: The Centre for Soil and Agroclimate Research, Bogor (2003)
Note : S1 = highly suitable, S2 = moderately suitable, S3 = marginal suitable, N = not suitable
F0 = none, F1 = low, F2 = medium, F3 = moderately high, F4 = very high

3. Results and discussions

3.1. Land systems and decision zones

Land system is based on Regional Physical Planning Programme for Transmigration (RePPProT) survey in 1980 and is still used. Basic concept of land system is to divide the landscape into areas meaningful for development planning. The land concept is based on ecological principles and presumes closely interdependent links between rock types, hydroclimatology, land form, soils and organism. The same land system is recognized wherever the same combination of such ecological or environmental factors occurs. A land system therefore, is not unique to one locality only, but considers all areas having the same environmental properties. Furthermore, because a land system consists always of the same combination of rocks, soil and topography it has the same potential, and limitation, wherever it occurs.

In Besitang watershed, there are eight names of land system, namely: Teweh, Maput, Bukit Pandan, Kajapah, Mantalat, Kahayan, and Pendreh (Table 2). Majority land system in Besitang Watershed is Teweh (50%), followed by Maput (16%), Bukit Pandan (13%), Kajapah (13%), Mantalat (3%), Kahayan (2%), and Pendreh (3.%). Only 0.02% is Air Hitam Kanan (Fig. 1). The land system was the used as a basis to determine decision zone (DZ) in this study. Decision Zone 1 is located in Bukit Pandan and Air Hitam Kanan Land Systems, Decision Zone 2 is located in Pendreh Land System, Decision Zones 3, 5, and 10 are located in Maput Land System, Decision Zones 4, 6, and 11 are located in Teweh Land System, Decision Zones 7 and 8 are located in Mantalat Land System, Decision Zone 9 is located in Kahayan Land System, and Decision Zone 12 is located in Kajapah land system. Based on the explanation above, look that the decision zones areas were different from each others and have broad scale. Hence, for detailed information and assessment (planning), need to rearrange the area of decision zone by stakeholder participation considering the interaction among land uses (ecological interaction).

Table 2. Land systems in Besitang Watershed

Sub-watershed	Land system name	DZ	Area	
			Hectare	Per cent
Upland stream	Air Hitam Kanan and Bukit Pandan	1	12,904.6	12.90
	Pendreh	2	3,150.6	3.15
	Maput	3	3,490.5	3.49
	Teweh	4	11,269.6	11.27
Middle stream	Maput	5	7,402.2	7.40
	Teweh	6	8,441.4	8.44
	Mantalat	7	878.5	0.88

Lower stream	Mantalat	8	2,442.1	2.44
	Kahayan	9	2,249.5	2.25
	Maput	10	4,756.6	4.75
	Teweh	11	30,214.1	30.20
	Kajapah	12	12,834.9	12.83
Total			**100,034.6**	**100.00**

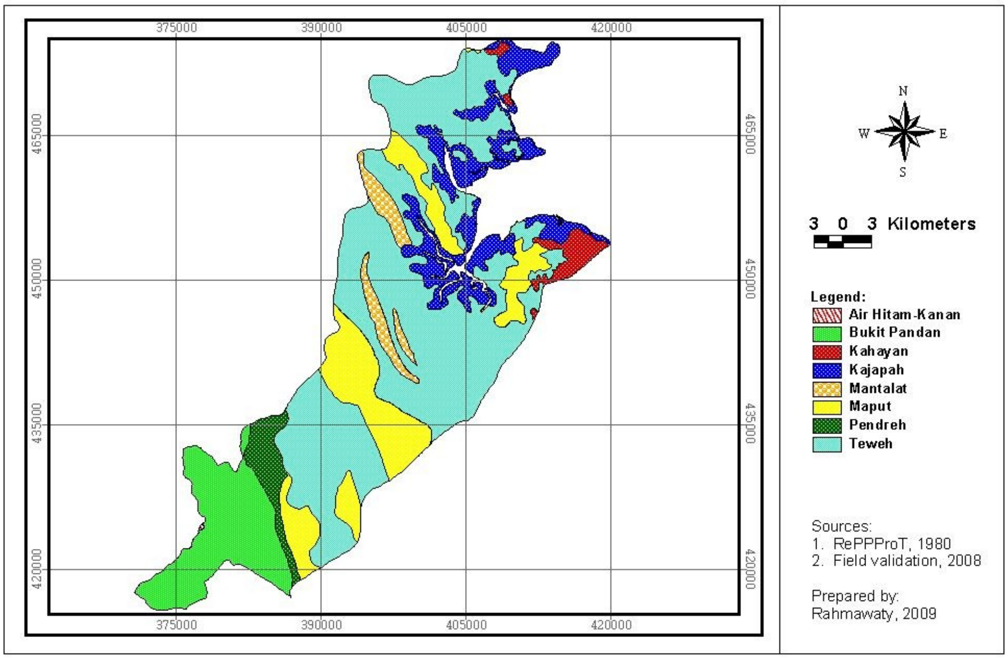

Figure 13. Map of land systems in Besitang Watershed, Langkat, North Sumatra, Indonesia

Fig.1: Map of land systems in Besitang Watershed, Langkat, North Sumatra, Indonesia.

3.2 Land suitability classification for palm oil

The adopted reference and criteria in LSC is the land suitability for agricultural plants (the Centre for Soil and Agroclimate Research, Bogor, 2003), the land quality and characteristics are temperature, water availability (annual rainfall), oxygen availability (drainage), root zone medium (texture, soil depth), nutrients retention (cation exchange capacity, base saturation, pH, C-organic), sodicity (alkalinity), terrain (slope, soil erosion), and flood hazard (inundation) (Table 1.).

Land suitability classification to oil palm in Besitang watershed is listed in Table 3 and delineated in Fig. 2. Actual land suitability class of oil palm under the different decision zones is N, S3, and S2. Majority of actual land suitability class of oil palm under the different decision zones is moderately suitable (S2) (DZ 3, 4, 5, 6, 9, 10, and 11.) Only in DZ 2 that has marginal suitability (S3) and only in DZ 1 and 12 that not suitable. There are several limiting factors for oil palm in Besitang watershed, namely: slope (eh), oxygen availability (drainage) (oa), nutrient retention (nr), flood hazard (fh), and root zone medium (rc). The decision zone that is located in upland stream sub-watershed, generally is limited by slope, in the middle stream is nutrient retention, and the lower stream is nutrient retention and flood hazard. For oil palm, rating can be improved by fertilization, terracing, and ditch/channel drainage. Hence, potential LSC for oil palm in DZ 2 and 7 could become S3.rc, in DZ 3 and 4 could become S2.rc, in DZ 5, 9, and 10 could become S2.fh, in DZ 6 and 11 could become S1, in DZ 8 could become S3.fh, and in DZ 11 could become S3.rc.fh.

Table 3. Suitability of land under the different decision zones to palm oil in the area

LSC	DECISION ZONE											
	1	2	3	4	5	6	7	8	9	10	11	12
Actual	N. eh	S3. eh. rc	S2. eh. rc	S2. eh. rc	S2. nr.f h	S2. eh. nr	S3. rc	S3. nr. fh	S2. oa. nr. fh	S2. nr. fh	S2.eh.nr S3.rc.fh	N. oa.fh
Potential	N. eh	S3. rc	S2. rc	S2. rc	S2. fh	S1	S3. rc	S3. fh	S2. fh	S2. fh	S1, S3.rc.fh	N. oa.fh

Note: LSC=land suitability classess, S1 = highly suitable, S2 = moderately suitable, S3 = marginal suitable, N = not suitable tc = temperature, wa = water availability, rc = root zone medium, nr = nutrient retention, eh = erosion hazard, fh = flood hazard

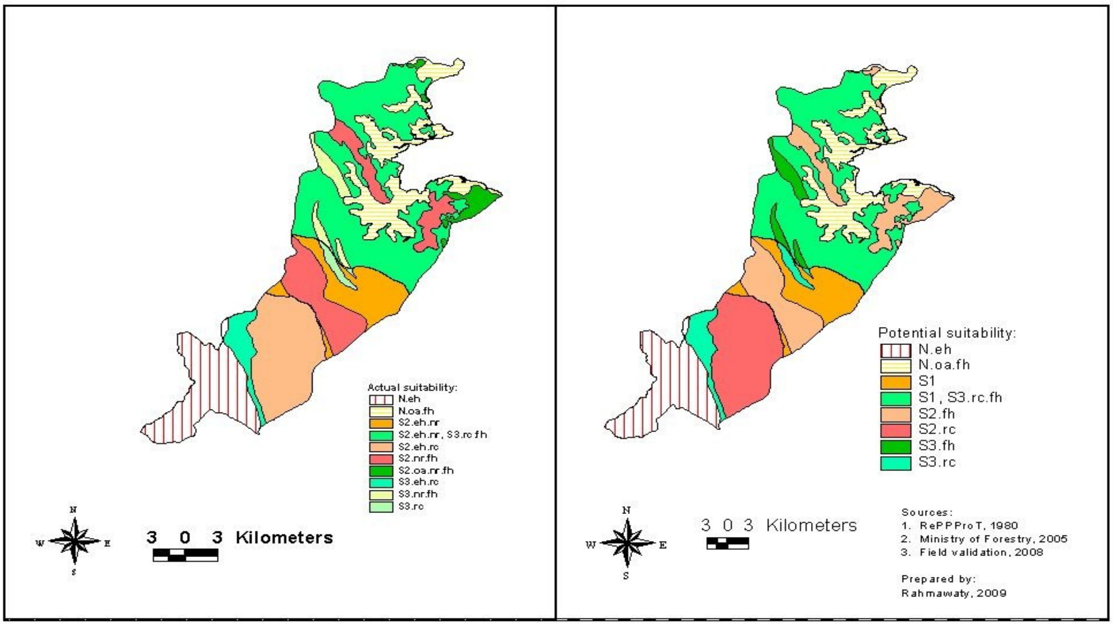

Figure 35. Map of suitability of land to oil palm in Besitang Watershed

Fig.2: Map of suitability of land to oil palm in Besitang Watershed

4. Conclusions

Actual land suitability class of oil palm under the different decision zones is moderately suitable (S2), marginal suitable (S3), and not suitable (N). There are several limiting factors for oil palm in Besitang watershed, namely: slope (eh), oxygen availability (drainage) (oa), nutrient retention (nr), flood hazard (fh), and root zone medium (rc).

Based on map of land suitability for oilpalm in this area, the decision zone that is located in upland stream sub-watershed, generally is limited by slope, in the middle stream is nutrient retention, and the lower stream is nutrient retention and flood hazard. For oil palm, rating can be improved by fertilization, terracing, and ditch/channel drainage.

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Production potential of *Leucaena* and fodder intercrops under alley farming system

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Introduction

Developing countries experiences great pressure to increase food production for the rapidly rising human population. The food pressure on land is so acute that there is little scope for extending the area under forage crops for increasing livestock population. More and more land brought under cultivation or crop intensification either in space (intercropping), in time (sequential cropping) or both is only feasible option to meet the demand. Interest has grown in the development of more production land use technologies involving intercropping of woody (particularly leguminous) species with food or forage crops in a agroforestry system. One such technology is alley farming for food and animal production, where the increase in production has come largely from improvement in productivity rather than from expansion of cultivated land.

Despite the potential benefits that can be derived from fodder based contour hedge row system on sloping lands, their use on flat fertile lands never gained popular acceptance among the farmers due to huge demand for food crops. The use of forage trees in conjunction with forage crops will be one of the principal strategies to meet the constraints of feed resources. Among the different tree species, *Leucaena* has become a model tree for alley farming due to its fast growth, N_2 fixing ability, nutritious fodder, adaptability on diverse conditions, high coppicing ability, etc. This plant was introduced in India in 19th century and it spread to many states for its multipurpose uses. *Leucaena* based alley cropping has extensively been reviewed on slopping land for food/fodder production (Kang *et al.* 1985 & 1990) but no information is available on performance of *Leucaena* based alley farming in irrigated agro-ecosystem. In alley farming, the hedgerow trees are kept pruned during the cropping period to minimize shading of the accompanying crops and favour crop productivity. Raut and Gill (1987) reported that grass-legume pastures are more persistent than grass-only fields. Therefore, this study was conducted with the objective to estimate the productive potential of leucaena based silvipastoral system along with fodder quality analysis.

Material and method

The present field studies were carried out in Punjab Agricultural University, Ludhiana and laboratory analysis was carried out in the Department of Animal Nutrition, Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana. Three diverse *Leucaena* sources viz., K-8 (*Leucaena leucocephala)*, K-156 (*Leucaena diversifolia*) and K-743A (*L. leucocephala x L. diversifolia*) selected on the basis of their diverse mimosine content were raised in randomized block design at the spacing of 4 x 2 m in four replications.

The *Leucaena* blocks were divided into two parts, annual (maize+cowpea followed by berseem + ryegrass) and perennial (napier bajra hybrid) type intercropping depending upon the nature of the fodder crop. The fodder crops viz., napier bajra hybrid (PBN-233, perennial), maize (J-1006) + cowpea (Cowpea-88) followed by berseem (BL-10) + ryegrass (Ryegrass No.1) were grown in between the rows of four years old *Leucaena* plants in their respective seasons each in two replications of three *Leucaena* sources. The recommended package of practices of Punjab Agricultural University were followed for the growing of fodder crops. Three harvest of *Leucaena* plants were taken during the month of April, August and December. The grasses were also harvested at their optimum maturity stage i.e., maize+cowpea (one harvest), ryegrass+berseem (four harvests) and napier bajra hybrid (three harvests). Green biomass was recorded in the field itself, whereas, the oven dry biomass at 70 ▪ 1 ▪C was recorded in the laboratory. Quadrat method (1 m^2) was followed to record the biomass and three quadrates per crop per replication were harvested to finally compute the yield on hectare basis.

The nutritional analysis for proteins, carbohydrates, total ash, mimosine and tannins from dried powder pure *Leucaena* leaves and mixed with inter-cultivated fodder crops in the ratio of 1:1, 1:2 and 1:3 was done as per the standard procedures. Crude protein, tannins and ash content were estimated as per the procedure of AOAC (1970); carbohydrates by following Dubois *et al.* (1956) and mimosine by rapid calorimetric method of Mastsumoto and Sherman (1951). The data on different parameters was suitably analysed on computer after following the standard procedure of Gomez and Gomez (1984).

Results and discussion

The observations recorded on the biomass and quality characteristics are presented in Tables 1-7.

Leucaena yield

The data in Table 1 shows that K-8 source produced the maximum green leaf biomass (3.74kg/plant per harvest), which was significantly higher than K-156 (2.6kg/plant) and K-743A (2.46kg/plant). These values calculated on hectare basis reflects 14.02, 9.75 and 9.22t green leaves/ha annually, respectively for above mentioned sources. The superior performance of K-8 in terms of biomass in comparison to other sources has also been reported earlier in different parts of the country (Nerkar 1984 and Relwani *et al.* 1985). The harvesting in the month of August recorded the maximum dry leaf biomass of 1.24 kg/plant, which was significantly higher than December harvest of 0.58 kg/plant but at par with April harvest (1.22 kg/plant). The higher biomass during monsoon season was due to favourable growth conditions than other two harvests. K-8 yielded 4.65t/ha of dry leaf biomass, which was significantly more than K-156 (3.52t/ha) and K-743A (3.22t/ha).

The non-edible dry biomass followed the trend of dry leaf biomass with respect to *Leucaena* sources and harvesting time. Irrespective of *Leucaena* sources, 2.82 kg dry fuelwood per plant was obtained annually, which is equivalent to 3.52 t/ha in addition to the leaf biomass. The time of harvesting had significant effect on the edible: non-edible biomass ratio (Table 1). Harvesting in the month of April was significantly superior in terms of fodder component (1.71) than other two harvests i.e., August (0.85) and December (1.05). The ratio more than one indicates the higher proportion of edible part than the non-edible portion. The leaf and shoot biomass during the monsoon harvesting was highest, still the leaf : shoot ratio during August harvesting was less than one, which indicated proportionally higher woody biomass production during April to August months than December to April or August to December.

The time of harvest as well as inter-source variation in *Leucaena* leaf biochemical content was also found significant (Table 2). The inter-source differences recorded in the present investigation are in accordance with the reports of Kaur *et al.* (2001). The value of protein, mimosine and tannin content were found positively correlated among themselves, whereas, ash and carbohydrate content were negatively related with other parameters. The carbohydrate and ash content also had negative relationship among themselves, maximum values for carbohydrate and minimum for ash content were recorded during monsoon harvest. In general, carbohydrates were comparatively less during monsoon season than summer/winter season, whereas, mimosine content in leaves increased with time from April to December. Higher mimosine content during winter than spring/summer season have also been reported earlier by Joshi *et al.* (1986). New leaves had higher mimosine than the older ones and the concentration is related to growth rates (better growth with higher mimosine). The effect of season/

time of year on fluctuations in mimosine concentration have also been observed (Gupta *et al.* 1992 and Arora & Joshi 1986). The anti-quality parameters, mimosine and tannins were minimum in K-743A followed by K-156 and K-8. The observed variations in quality and antiquality factors in present studies are in accordance to other earlier studies (Tangenjaja *et al.* 1986, Lahene *et al.* 1987 and Faria Marmol 1994).

Fodder yield

The inter-cultivated fodder yields were least affected by the *Leucaena* plants. The green fodder yield for different crops is presented in Table 3. The maize + cowpea yield though varied non-significantly in alley and open condition but the yield was slightly more in alleys. Comparatively more succulence was observed in maize + cowpea when grown in *Leucaena* corridors than in open i.e., 83.04 and 80.78 per cent moisture content, respectively. The higher yield in hedgerows is due to better penetration of solar radiation with regular lopping and nitrogen fixation ability of *Leucaena*. Taneja *et al.* (1994-95) recorded 52 per cent higher yield of maize under alleys of *Leucaena* over maize on no-tree plot, while Hazra (1993) and Chamshama *et al.* (1998) recorded same yield of maize in open and in *Leucaena* hedgerows. The increase in productivity through intercropping of maize, cowpea and woody forage of *Leucaena* may be due to the efficient utilization of natural resources.

The *Leucaena* inter-source differences on ryegrass + berseem yield were significant. The average maximum fodder production of 19.7 t/ha per harvest was in K-8 alley, which was significantly superior to K-156 and K-743A (17.1 and 16.4 t/ha, respectively) but at par with yield under control 18.3 t/ha (grown in open). Total dry biomass of 7.7t/ha reflects 89.55 per cent moisture and 10.45 per cent roughage in the fodder in *Leucaena* based silvi-pastoral model (Table 3). In total, the crop yield of berseem+ryegrass under K-8, K-156 and K-743A was recorded to be 78.8, 68.5, 65.8 t/ha in *Leucaena* rows and 73.2t in open (Table 7). The different harvests also had significantly variable fodder yield.

The data pertaining to napier bajra hybrid (perennial grass) biomass depicted per cut average green matter yield of 43.0 t/ha, which was equal to the control value of 42.75 t/ha (Table 3). The total annual napier yield (t/ha) in *Leucaena* alleys was estimated to be 137.5 (K-8), 127.5 (K-156), 122.5 (K-743A) , which was at par to the yield in open (128.7). The results revealed that the intercropping of *Leucaena* and napier bajra had positive interaction.

The interaction in *Leucaena* based silvi-pastoral system on growth and/or development was not found competitive rather facilitatory. Regular harvesting of *Leucaena* plants as well as the leguminous crop mixture in the annuals (cowpea with maize followed by berseem with ryegrass) showed stable interaction rather than negative tree-crop interaction. Singh (1988), Saharan *et al.* (1989), Gill and Tripathi (1991), Mureithi *et al.* (1995) also reported the positive association of *Leucaena* with forage crops like hybrid napier, lucern, oat and other cereal forages.

Leucaena supplemented feed quality

Foliage of *Leucaena* is highly palatable, nutritious and relished by cattle, goat and wildlife but it cannot be used as sole feed because of presence of non-protein amino acid, mimosine [β{N-3hydroxy-4(H) pyridone} amino propionic acid]. Thus, *Leucaena* leaves were mixed with inter-cultivated forage crops for supplemented feed quality evaluation.

Protein and mimosine are two important components among the studied parameters in the feed. The nutritive values of pure *Leucaena* sources presented in table 2, indicated that the anti-quality bio-chemicals (mimosine and tannins) were comparatively less in K-743A than K-156 and K-8, whereas, other important biochemicals like crude protein exhibited reverse trend. The data on qualitative parameters of *Leucaena* mixed with ryegrass+berseem, maize + cowpea and napier bajra hybrid in different proportion presented in Table 4-6, exhibited significant differences in values with respect to different *Leucaena* sources, the proportion of mixing and their interaction in almost all the parameters. The anti-quality parameters were found in the order of K-743A<K-156<K-8 at all mixture levels. Lahene *et al.* (1987) and Norton *et al.* (1995) also reported the similar trend of mimosine and tannins

in these *Leucaena* sources.

Irrespective of the *Leucaena* source, the value of protein, carbohydrate, mimosine and tannins decreased, while the ash content increased with the increase in proportion of inter-cultivated fodders (Table 4-6). The reduction in the carbohydrate, mimosine and tannin content was drastic (70-76%) but slight in protein (4 to 16%) with the increase in proportion of forage crops in *Leucaena* from 1:1 to 1:3 ratio. Kaur and Gupta (2003) observed very low concentration of mimosine and tannins in blended fodders of berseem + shaftal : subabul foliage in the ratio of 40:60 and 60:40, which were quite below the toxic level. The level of protein and carbohydrates in blended fodder were also found in accordance with the recommended standards. The feeding of *Leucaena* after mixing with other forages to minimize the anti-quality factors also find the support of Devendra (1982), where 50 per cent amount of *Leucaena* forage in diet has been recommended. Norton (1994) emphasized 30-50 per cent *Leucaena* in the diet for optimum performance of cattle, sheep and goats. *Leucaena* leaves have also been used successfully to increase the protein content and nutritive value of the silages (Tandraatmadja *et al.* 1993).

Anti-nutritive factors assume greater significance when tree leaves are major component of the diet. Although subabul contain an array of secondary plant metabolites, the major compounds that affect nutritive value are the non-protein amino acid, mimosine and tannins. The mimosine content in the fodder can be diluted to a greater extent by appropriate selection of leucaena source and mixing the inter-cultivated fodder in the ratio of 1:2 to 1:3. As a rule no more than 30-50 per cent leucaena in the diet should be fed for the optimum performance of animals. *Leucaena* leaf can also be used successfully to increase the protein content and nutritive value of silage. K-743A with other fodder crops (1:3) yielded lowest mimosine and tannin contents, but as mentioned above this *Leucaena* source is comparatively less productive than K-156 and K-8. Thus, keeping in mind the quantity and quality considerations, K-8 mixed in the ratio of 1:2 with other inter-cultivated annual as well as perennial fodders will be optimum for recommendation.

***System* productivity**

The *Leucaena* based silvi-pastoral model was found highly productive (Table 7). Growing of annual crops [Maize+cowpea (summer) – berseem+ryegrass (winter)] and perennial crop (napier bajra hybrid) produced 98.7 and 128.7 tonnes green biomass per hectare, whereas, when grown in *Leucaena* alleys the total fresh edible biomass was estimated to be 110.3 t/ha and 140.2 t/ha, respectively. On dry weight basis, these figures were equivalent to 16.3 t/ha and 27.4 t/ha, with the additional shoot biomass (fuelwood) increasing the figure on fresh weight basis to 120 t/ha and 150t/ha and dry weight bassis to 19.8 t/ha and 30.9 t/ha, respectively (Table 7). The productivity of the system, however, varied with respect to *Leucaena* sources and followed the order of K-8>K-156>K-743A on green as well as dry weight basis. One hectare of *Leucaena* + annual crops produced fodder equivalent to 1.12 ha of sole annual crops, whereas, the total dry biomass (edible + non-edible) was equivalent to 1.5ha. Similarly, One hectare of *Leucaena* + perennial crop (napier bajra hybrid) produced fodder equivalent to 1.09 ha of sole napier bajra hybrid, whereas, the total dry biomass including fuel wood was equivalent to 1.45ha. In terms of protein supplement, *Leucaena* based silvi-pastoral model produced 55.03 and 33.03 per cent more protein with perennial (napier bajra hybrid) and annual (maize+cowpea followed by berseem+ryegrass) fodder crops, respectively than sole fodder crops. It is, therefore, advantageous to grow perennial crop in *Leucaena* alleys than the annual crops to make saving in cost of production. The ratooning of napier bajra hybrid also offers an opportunity of continuous supply of green forage. The system maintains higher soil moisture and organic carbon for sustainable biomass production for longer period. Grewal (1995) recorded 19t/ha/yr napier grass in addition to 1.9 tonnes of pruned green foliage in *Leucaena*-napier grass system and recommended that this system for fuelwood and fodder is far superior than raising sole crops under rainfed conditions. Bhatt *et al.* (2006) recorded that *Leucaena*-forage crop based systems had the 1.5-2.25 times higher productivity than pure pasture based system.

This study establishes the high potential of subabul as a fodder cum fuel tree in agroforestry systems in irrigated agro-ecosystem. Recently its use in paper industry has encouraged the farmers of Southern states of India for its adoption in farm forestry/agroforestry. The adoption of subabul based silvi-pastoral system in other states will also provide the high level of fodder and fuel output, stabilize the agro-ecosystem and provide employment to rural people

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Leucaena - Napier bajra hybrid

Leucaena - Ryegrass+berseem

Leucaena – Maize+cowpea

Fig.1 *Leucaena* based silvi-pastoral system

Table1. *Leucaena* green and dry biomass (kg/plant)

Leucaena source	Leaf biomass				Shoot biomass				Leaf: shoot ration			
	April	Aug	Dec	Mean	April	Aug	Dec	Mean	April	Aug	Dec	Mean
K-8	5.00 (1.55)	4.10 (1.45)	2.13 (0.73)	3.74 (1.24)	3.05 (1.06)	4.75 (1.72)	1.98 (0.72)	3.26 (1.17)	1.64 (1.48)	0.86 (0.84)	1.11 (1.02)	1.15 (1.20)
K-156	3.13 (1.11)	3.30 (1.18)	1.58 (0.54)	2.67 (0.94)	1.78 (0.62)	3.83 (1.37)	1.49 (0.53)	2.37 (0.84)	1.76 (1.78)	0.76 (0.86)	1.08 (1.00)	1.13 (0.89)
K-743A	2.98 (1.01)	3.10 (1.09)	1.32 (0.46)	2.46 (0.86)	1.67 (0.59)	3.72 (1.35)	1.35 (0.48)	2.25 (0.81)	1.84 (1.73)	0.82 (0.81)	0.97 (0.96)	1.09 (0.83)
Mean	3.70 (1.22)	3.50 (1.24)	1.67 (0.58)	2.95 (1.01)	2.16 (0.76)	4.10 (1.48)	1.60 (0.58)	2.62 (0.94)	1.71 (1.61)	0.85 (0.84)	1.05 (0.99)	2.78 (0.97)

* Figures in parentheses depict the dry biomass

C.D. at 5% level of significance

Leucaena source	0.31 (0.07)	0.29 (NS)	NS (NS)
Harvest	0.31 (0.07)	0.29 (0.10)	0.20 (0.18)
Leucaena source x harvest	NS (NS)	NS (NS)	NS (NS)

Table 2. Quality parameters of different *Leucaena* sources at variable harvesting stages

***Leucaena* Source**	**Crude protein (%)**				**Carbohydrate (%)**				**Ash (%)**				**Mimosine (%)**				**Tannins (%)**			
	Apr	**Aug**	**Dec**	**Mean**	**Apr.**	**Aug.**	**Dec**	**Mean**	**Apr**	**Aug**	**Dec**	**Mean**	**Apr**	**Aug**	**Dec**	**Mean**	**Apr**	**Aug**	**Dec**	**Mean**
K-8	22.00	22.85	27.30	24.05	13.40	7.80	16.31	12.50	7.40	9.22	7.8	8.14	1.60	2.10	3.20	2.30	2.77	3.70	4.80	3.76
K-156	24.20	23.26	29.40	25.20	11.92	7.70	18.42	12.68	7.42	9.19	7.3	7.97	1.18	1.64	2.80	1.87	3.20	3.30	4.10	3.53
K-743A	21.20	25.00	27.50	24.20	14.12	8.20	22.00	14.77	7.16	9.23	7.6	7.99	0.80	1.20	2.20	1.40	2.60	2.90	4.40	3.35
Mean	22.40	23.70	28.06	-	13.14	7.90	18.91	-	7.32	9.21	7.56	-	1.19	1.64	2.73	-	2.85	3.30	4.43	-

C.D. at 5% level of significance

Source	0.09	0.06	0.16	0.04	0.14
Harvest	0.13	0.07	0.19	0.04	0.15
Source x Harvest	0.16	0.11	0.20	0.06	0.24

Table 3. Fodder crop yield* under *Leucaena* based silvi-pastoral model (t/ha)

***Leucaena* Source**	**Maize+cowpea green (dry yield**	**Ryegrass + berseem green (dry) yield**						**Napier bajra hybrid green (dry) yield**				
		C_1	**C_2**	**C_3**	**C_4**	**Mean**	**Total**	**C_1**	**C_2**	**C_3**	**Mean**	**Total**
K-8	29.5 (5.0)	18.3 (1.7)	21.9 (2.4)	21.0 (2.5)	17.6 (2.3)	19.7 (2.2)	78.8 (8.9)	36.25 (5.5)	43.75 (8.0)	57.5 (11.75)	45.7 (8.50)	137.5 (25.25)
K-156	27.8 (4.9)	17.5 (1.6)	21.5 (2.3)	14.7 (1.7)	14.8 (1.9)	17.1 (1.9)	68.5 (7.5)	32.5 (4.75)	40.0 (7.25)	55.0 (11.25)	42.5 (7.75)	127.50 (23.25)
K-743A	27.5 (4.6)	17.0 (1.5)	19.9 (1.6)	14.6 (1.6)	14.3 (1.9)	16.4 (1.6)	65.8 (6.6)	31.25 (4.5)	38.75 (7.0)	52.5 (10.75)	40.75 (7.5)	122.50 (22.25)
Control	25.5 (4.9)	22.0 (2.2)	21.5 (2.3)	14.2 (1.6)	15.5 (2.2)	18.3 (2.1)	73.2 (8.3)	32.5 (5.5)	41.25 (6.5)	55.0 (9.25)	42.75 (7.0)	128.70 (21.25)
Mean	28.5 (4.8)	18.7 (1.7)	21.2 (2.1)	16.1 (1.8)	15.5 (2.1)	17.7 (1.9)		33.0 (5.0)	40.75 (7.25)	55.00 (10.75)	42.98 (7.92)	

*Figures in parentheses depict the dry biomass

C.D. at 5% level of significance

Leucaena source	N.S. (N.S.)	16.0 (3.0)	N.S.(N.S.)
Harvest	-	16.0 (N.S.)	49.0 (18.0)
Leucaena source x Harvest	-	32.0 (N.S.)	N.S. (N.S.)

Table 4. *Leucaena* : ryegrass + berseem ratio and nutritional value

***Leucaena* Source**	**Crude protein (%)**				**Carbohydrate (%)**				**Ash (%)**				**Mimosine (%)**				**Tannins (%)**			
	1:1	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**
K-8	20.63	20.08	19.81	20.17	5.70	2.85	1.42	3.32	9.07	9.38	9.53	9.32	1.16	0.55	0.38	0.69	1.80	0.90	0.40	1.03
K-156	21.50	20.60	20.25	20.78	5.96	2.98	1.47	3.47	8.98	9.32	9.49	9.26	0.90	0.44	0.27	0.53	2.20	1.10	0.50	1.26
K-743A	20.92	20.28	20.29	20.49	6.06	3.03	1.51	3.53	8.99	9.32	9.50	9.27	0.70	0.33	0.19	0.40	1.60	0.80	0.30	0.90
Mean	21.01	20.32	20.11		5.90	2.95	1.47		9.01	9.34	9.50		0.91	0.44	0.28		1.86	0.93	0.40	

C.D. at 5% level

Leucaena source	0.25	0.06	0.08	0.04	0.08
Harvest	0.24	0.07	N.S.	0.04	0.06
Leucaena source x Harvest	N.S.	0.10	N.S.	0.06	0.13

Table 5. *Leucaena* : maize + cowpea ratio and nutritional value

Leucaena source	Crude protein (%)				Carbohydrate (%)				Ash (%)				Mimosine (%)				Tannins (%)			
	1:1	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**	**1:1**	**1:2**	**1:3**	**Mean**
K-8	19.52	18.01	16.31	17.88	6.05	3.03	1.51	3.53	8.57	8.85	8.89	8.77	1.20	0.60	0.40	0.73	1.60	0.81	0.42	0.94
K-156	20.31	18.54	17.65	18.83	6.27	3.13	1.56	3.65	8.48	8.88	8.87	8.74	0.93	0.46	0.24	0.54	1.69	0.84	0.41	0.98
K-743A	19.78	18.18	17.39	18.45	7.06	3.53	1.76	4.11	8.50	8.83	8.88	8.73	0.80	0.42	0.22	0.48	1.66	0.83	0.40	0.96
Mean	19.87	18.24	17.05		6.46	3.23	1.61		8.51	8.85	8.88		0.97	0.49	0.28		1.65	0.82	0.42	

C.D. at 5% level

Leucaena source	N.S.	0.17	N.S.	0.14	0.09
Harvest	1.70	0.17	N.S.	0.14	0.09
Leucaena source x Harvest	N.S.	0.29	N.S.	N.S.	0.16

Table 6. *Leucaena* : napier bajra hybrid ratio and nutritional value

Leucaena Source	Crude protein (%)				Carbohydrate (%)				Ash (%)				Mimosine (%)				Tannins (%)			
	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean	1:1	1:2	1:3	Mean
K-8	18.02	16.04	15.34	16.46	6.12	3.06	1.53	3.57	9.70	10.04	10.20	9.98	1.30	0.65	0.40	0.78	1.72	0.86	0.43	1.00
K-156	18.81	16.54	15.40	16.91	6.48	3.07	1.54	3.69	9.43	9.82	9.96	9.74	0.92	0.48	0.26	0.55	1.82	0.91	0.45	1.06
K-743A	18.28	16.18	15.14	16.53	6.90	3.45	1.72	4.02	9.45	9.78	10.00	9.74	0.82	0.44	0.24	0.50	1.66	0.83	0.40	0.96
Mean	18.37	16.25	15.29	-	6.50	3.19	1.59	-	9.53	9.88	10.05	-	1.01	0.52	0.30	-	1.77	0.86	0.42	-

C.D. at 5% level

Leucaena source	N.S.	0.29	N.S.	0.15	0.62
Harvest	1.43	0.30	N.S.	0.15	0.62
Leucaena source x Harvest	N.S.	N.S.	N.S.	N.S.	N.S.

Table 7. Biomass production (tonnes) in *Leucaena* based silvi-pastoral model on hectare basis

Leucaena source	Fresh biomass (t/ha)				Dry biomass (t/ha)			
	Leucaena		Perennial (napier bajra hybrid)	Annual (cowpea-maize + berseem-ryegrass)	*Leucaena*		Perennial (napier bajra hybrid)	Annual (cowpea-maize + berseem-ryegrass)
	Leaves	Shoot			Leaves	Shoot		
K-8	14.025	12.075	137.5	108.3 (29.5+78.8)	4.650	4.387	25.25	13.9 (5.0+8.9)
K-156	9.750	8.850	127.5	96.3 (27.8+68.5)	3.525	3.150	23.25	12.4 (4.9+7.5)
K-743A	9.225	8.437	122.5	93.3 (27.5+65.8)	3.187	3.037	22.25	11.2 (4.6+6.6)
Average	11.00	7.132	129.2	99.3 (28.3+71.0)	3.787	3.525	23.58	12.5 (4.8+7.7)
Control	-	-	128.7	98.7 (25.5+73.2)	-	-	21.25	13.2 (4.9+8.3)

Leucaena source	Fresh biomass (t/ha)				Dry biomass (t/ha)			
	Perennial crop + *Leucaena* leaves	Perennial crop + *Leucaena* (leaves + shoot)	Annual crops + *Leucaena* leaves	Annual crops + *Leucaena* (leaves + shoot)	Perennial crop + *Leucaena* leaves	Perennial crop + *Leucaena* (leaves + shoot)	Annual crops + *Leucaena* leaves	Annual crops + *Leucaena* (leaves + shoot)
K-8	151.53	163.60	122.33	134.40	29.90	34.29	18.55	22.94
K-156	137.25	146.10	106.05	114.90	26.77	29.92	15.92	19.07
K-743A	131.73	140.16	102.53	110.96	25.44	28.47	14.39	17.42
Average	140.17	149.95	110.30	120.09	27.37	30.89	16.29	19.81
Control	128.70	128.70	98.70	98.70	21.25	21.25	13.20	13.20