Sustainable Bioenergy Solutions for Tomorrow (BEST) – Case India: Madhya Pradesh, Maharashtra and Tamil Nadu

WP 2 Radical improvement of bioenergy supply chains

Task 2.3: Challenges and opportunities in the utilization of Indian biomass resources

Report on

Subtask 2.3.1 New biomass resources and sustainable land use solutions

Prospects of biomass-based energy project development in India: A synthesis from Indian Forest Service officers' survey

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Sustainable Bioenergy Solutions for Tomorrow

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Prospects of biomass-based energy project development in India: A synthesis from Indian Forest Service officers' survey

SUMMARY: Issues related to energy access and energy security are considered as central key to the sustainable development aspirations of developing countries like India. Biomass-based energy plays a significant role in the total primary energy consumption of the country. Being a tropical country, India has tremendous potential for energy generation through forest-based biomass and agricultural residues. This report is derived from a questionnaire survey to the Indian Forest Service (IFS) officers who are involved in managing forest resources in different parts of the country. The primary aim of the report is to set the context for understanding the current state and future evolution of biomass supply, wasteland development, social willingness and related issues in the country. The challenges and opportunities of bioenergy promotion are also delineated briefly.

1. INTRODUCTION

India has the world's second largest population of 1.24 billion in 2011 and the world's seventh largest landmass (World Bank, 2012). The country has achieved rapid and remarkable economic development in the past two decades and became the world's tenth largest economy in 2011. With its relatively young population with a median age of 26.2 years, India is expected to take over China as the world's most populous nation around 2025 (IEA 2011). The consequence of both economic and population growth is expected to increase energy demand that is needed to be met. Presently about 95% of India's current commercial energy demand is met by domestic production of coal (51%), natural gas (9%), and imported oil (35%) while the rest is satisfied by hydro and nuclear energy. Since 2000, the Indian economy has increased at an average rate of approximately 7%, but failed to achieve a balanced economic growth between rural urban and rural areas (IEA 2011). For instance, 37% of the national population and 42% of the rural population live below poverty line. However, the fast economic growth did not remarkably improve the energy sector and remains energy poor in rural areas (Balachandra 2012). Nearly one-quarter of the national population and 44% of the rural population do not have access to electricity (IEA 2012; Ministry of Power 2012). Per capita electricity consumption is only 814 kWh, which is only 24% of the world average (Ministry of Power 2012) However, biomass still remain the important sources of primary energy in India. Biomass fuels are predominantly used in rural households for cooking and water heating, as well as by traditional and artisan industries.

India has a long history of energy planning and program interventions. The Government of India (GoI) has formulated several policies to increase the domestic production of biomass-based fuel since it was recognized being a local, widely accessible and renewable resource, and was potentially the most suitable to alleviate macro and micro concerns raised by the rural energy crisis (Shukla 1997). The GoI adopted National Policy on Biofuels in 2008 targeting a 20% blend of biofuels both for biodiesel and bioethanol by 2017 (MNRE, 2009).

However, the National Policy on Biofuels did not mention specifically the role of forest and crop biomasses for achieving the target. Therefore, it is difficult to anticipate the future development of these resources. Moreover, the information related to the opportunities and challenges associated with promotion of bioenergy in India from environmental and socio-economic perspectives is scanty. Most of the earlier studies focused on the 'first generation' biofuels crops since the technologies for converting 'second generation' biofuels crops (e.g., perennial grasses, woody crops, agricultural and forest residues) have not been well developed in India (Ravindranath et al. 2011). In addition, various challenges for developing large-scale bioenergy projects in India associated with lack of available land for large-scale energy crop plantations, lack of data related to indirect and direct impacts of bioenergy production on food security, and lack of financing and marketing institutions for bioenergy in India (Das and Priess, 2011). A recent study revealed that the lack of public acceptance and political support, impacts on biodiversity, and lack of technologies and infrastructure were the considerable challenges to the development of forest-based bioenergy projects in India (Halder et al. 2014).

Stakeholders' perceptions and attitudes are considered as important elements for development of renewable and bioenergy in many countries in Europe, North America and Asia (Curry et al. 2005; Sudhakara Reddy and Balachandra 2006; Greenberg 2009; Halder et al. 2010; Qu et al. 2012). The gap in understanding between energy companies and the public, as well as the lack of scientific knowledge on biomass-based energy among different stakeholders were seen as the major causes for the failure of energy innovation projects. Therefore, providing scientific knowledge of the expert level stakeholders that could help in establishing trust is paramount. Expert knowledge is also required because new technology helps to construct very complex systems from the everyday users' perspective (Giddens, 1990). In the Indian context, the IFS (Indian Forest Service) officers can be considered as one of the most important stakeholders in bioenergy related projects (Halder et al. 2014). The information from the IFS officers is quite useful for getting the first level background information for developing biomass-based energy projects in different parts of the country. During autumn 2013, 31 IFS officers participated in a 'Mid-Career Training' program, which was organized by the University of Eastern Finland (UEF) and the Ministry of Environment and Forest (MoEF), GoI. The present study explored those IFS officers' opinions in order to understand their views and perceptions of various aspects of developing biomass-based energy projects in India. Synthesizing their opinions towards forest-based bioenergy could provide relevant information about the scope of modern bioenergy sector development in India, which is expected to be important from the policy perspectives. Based on the IFS officers' perception, this paper highlights the supply potential of forest and crop biomass feedstock, problems and prospects associated with bioenergy plantation in wasteland and farmers' attitudes towards development of bioenergy projects. The study is important in providing baseline information for the planning of biomass-based energy plants in India.

2. MATERIALS AND METHODS

The study involved a questionnaire-based survey method among a group of IFS officers who participated in 'Mid-Career Training' program at the UEF during autumn 2013. The study aims to explore the opinions of IFS officers towards development of biomass-based energy as a future source of producing renewable energy in India. The survey was based on respondents' knowledge and understanding on the relevant issue. All the 31 IFS officers participated in the survey and there was no non-response bias. It has to be mentioned that the IFS cadre has about 2000 officers working in India including those who have joined the service and those who are working in the top most hierarchy after 25-30 years of service in various regions of the country (Halder et al. 2014). However, the survey covered less than 1% of the total number of IFS officers, and about 90% of them belonged to the middle level category with 10-20 years of working experience in the IFS cadre under the MoEF, Government of India.

The questionnaire consisted of both open and closed-ended items. The questionnaire consisted of three sections. In the first section, the questions were designed to explore the supply and potential of both forest and agriculture-based biomass for bioenergy production. The second section mainly consisted of wasteland issues related to current utilization and prospects of energy wood plantation. The third section mainly focused on the socio-cultural aspects of bioenergy development. Altogether about 30 (multiple choice and Likert-type) questions were constructed for this survey of which 18 were open-ended and 12 were closed-ended. The items on the Likert-type scale were selected after a comprehensive literature review and expert consultations. The questions were developed to give extra open space for the respondents where they could express their opinion in the case when a particular answer could not cover their accurate position.

3. RESULTS AND DISCUSSION

3.1 Supply of biomass potential from forest resources

3.1.1 Supply of biomass from forests

The IFS officers were asked about the potentialities of biomass from forests for bioenergy production. About 60% of them viewed that the supply potential of biomass from Indian forests was quite low. However, about 25% of the respondents viewed that the potentiality was medium while only about 15% of them informed that the potentiality was high. Although the biomass potential from the forests of most of the states are low, but some of the forest areas in the states of Andhra Pradesh, Kerala, Madhya Pradesh and Uttarakhand, the potential is still promising with some extent. A follow-up question was asked to the respondents whether the potentiality of forest biomass would be increased in the future in their jurisdictions. More than half of the IFS officers informed that the biomass potentiality could be increased in the future **(Figure 1)**. The respondents identified that the main interventions required would be raising new plantations and collection of residues during forest operations. About 40% of the respondents perceived that the potentiality of supplying

forest biomass would not be increased mainly due to shrinkage of the governmental forest resources, lack of suitable land for afforestation, less tree resources on privately owned land and strict government regulations (e.g., felling ban in natural forests).

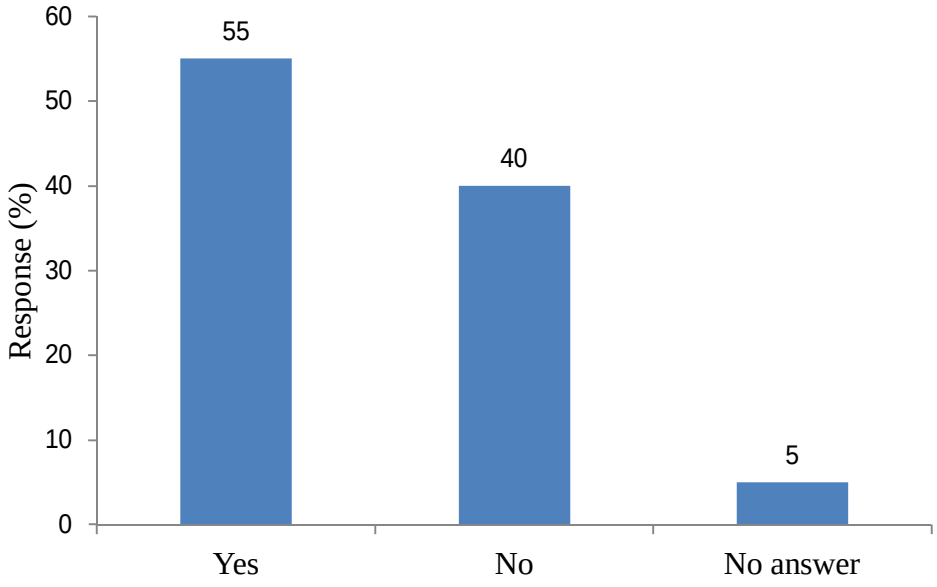

Figure 1. Respondents' answers whether the potentiality of forest-based bioenergy would be increased in future.

3.1.2 Supply of biomass potential from forest-based industries

Saw mills are the main industries for supplying biomass in India. When logs are processed in saw mills for primary wood products, then residues are generated which mainly consist of discarded logs, bark, saw dust and shavings. These residues are attractive for bioenergy production. In this context, the IFS officers were asked whether there existed any saw mills in their area, and what they thought about the potentiality for supplying sawmill residues for bioenergy production. Regarding the first question, all respondents informed that there were saw mills in their jurisdictions. With regard to the potentiality, about 55% of the respondents' views were between medium to high **(Figure 2)**. However, about 40% of the respondents informed the potentiality of saw mills residues for bioenergy production as low while another 5% were not sure about such potentiality. It appeared that the potentiality would vary among the States as the respondents were from different States in India. The potentiality of sawmill residues seemed to be better in the States of Andhra Pradesh, Karnataka, Kerala and Uttarakhand.

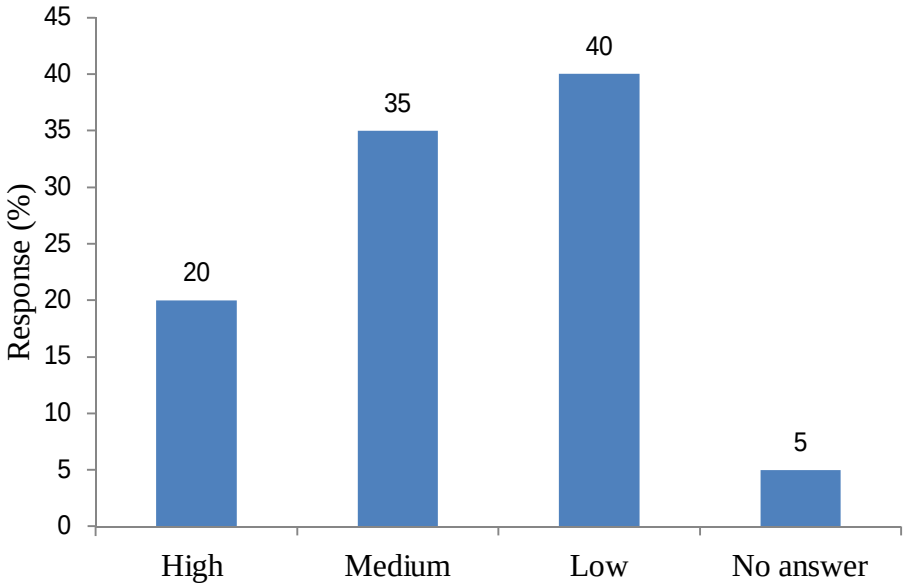

Figure 2. Respondents' answers about the potentiality of sawmills' residues for bioenergy production in their area.

3.1.3 Preferred tree species for raising energy wood plantation

It has been reported that there are vast amount of waste land and tracts available in India, which have remained barren for decades (NRSA 2005; Ravindranath et al. 2011). Part of these lands can be exploited for energy wood plantations. However, the selection of tree species for such plantations depends on site conditions, topography, weather, and soil quality. In these regards, the IFS officers were asked to select three suitable tree species that can be promising for energy wood plantation. Based on their experiences they selected some 30 tree species of which the top 3 most suitable species are *Acacia spp.*, *Eucalyptus spp.* and *Prosopis juliflora*. With regard to their opinions, the top 10 preferred tree species for wood energy plantation are shown in **Table 1**.

Table 1. Top 10 suitable tree species for wood energy plantation in India

No.	Name of tree species	Response (%)
1	*Acacia spp.*	52
2	*Eucalyptus spp.*	39
3	*Prosopis juliflora*	32
4	*Leucaenia leucocephala*	16
5	*Populus spp.*	16
6	*Pongamia pinnata*	13
7	*Casuarina spp.*	10
8	*Shorea robusta*	7
9	*Quercus spp.*	6
10	*Melia azedarach*	6

3.1.4 Challenges for promoting bioenergy from forest biomass

Tree planting on waste and barren tracts is a potential tool for arresting the increasing misuse and over exploitation of these lands and environmental degradation. This eventually helps in forest restoration, and will increase the forest biomass. However, in India, the promotion of afforestation and reforestation involves a number of institutional and policy impediments afforestation/reforestation programmes and policy failure on recovery of the encroached wasteland (Balooni and Singh 2007). In this context, the IFS officers were asked to identify three main challenges related to the producing bioenergy from forest biomass from both governmental and private owned lands in India. It appeared that the most of the challenges were considered as lack of societal knowledge and awareness of future biomass fuel supply, and lack of adequate governmental policy on land management, followed by small land holdings **(Table 2**).

Table 2. Main challenges for promoting bioenergy from forest-based biomass in India

No.	Types of challenges	Response (%)
1	Lack of knowledge and awareness in society of future biomass fuel supply	20
2	Lack of adequate governmental policies on land management	19
3	Small land holdings	18
4	Lack of management of existing forest resources	16
5	Lack of suitable land for afforestation	11
6	Biotic pressure on existing land and forests resources	10
7	Lack of motivation of farmers	9

Furthermore, the IFS officers were asked to inform their concerns over the impact of fuelwood collection on the existing forest resources. About 80% of the respondents considered the present practices of collecting fuelwood from forests responsible for the deteriorating conditions of the existing forests **(Figure 3)**. They also considered that such a practice was the major cause of concern for forest deforestation and forest degradation in the country.

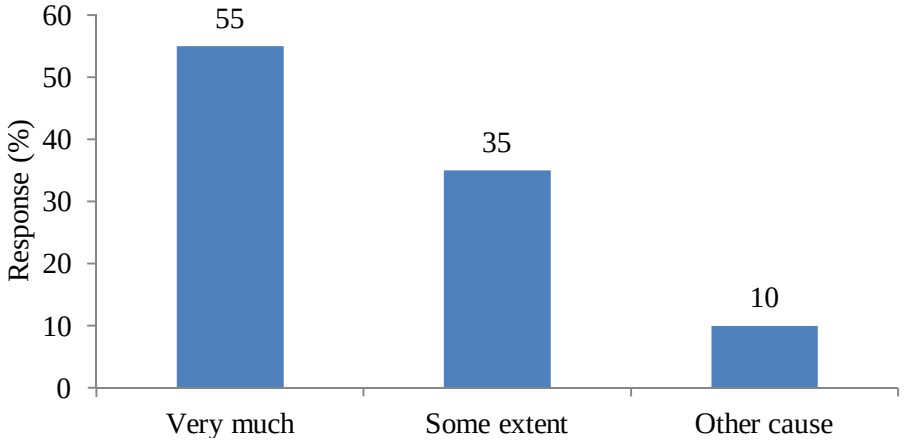

Figure 3. Respondents' answers on the severity of current practices of fuelwood collection on the existing forest resources

3.2 Supply of biomass potential from crop residues

India has about 140 million hectare of arable and permanent crop land, which constitutes about 43% of the total geographical area of the country (Ref.?). The main crops are rice, wheat, pulses, oil seeds and other commercial crops including sugarcane, cotton, coconut, jute, mulberry etc. Cereals dominate the agricultural crops followed by pulses, cotton and sugarcane. Several studies have revealed that the residues produced from agricultural crops are promising sources for energy generation in India (Ravindranath 1995; MSSRF 2011). In this regard, the IFS officers were asked to inform about the potentiality of supplying crop residues for bioenergy production. About 60% of the respondents' answers fell between high to medium category while 35% viewed that the supply potential was low. Another 5% did not have any idea about the supply potential of crop residues for bioenergy production. The production and supply potential of crop residues vary from State to State and from region to region depending on respective agro-climate conditions and domestic use. The IFS officers were asked to select the three most promising crop residues for supplying biomass for bioenergy production. The respondents identified some 18 crops of which the 3 most promising crops were paddy, wheat and sugarcane. According to their preferences, the top 10 promising crops and crop residues are shown in **Table 3.**

Table 3. Promising crops and crop residue for bioenergy production

No.	Name of crop	Name of residue	Response (%)
1	Paddy	Straw, husk	19
2	Wheat	Sraw, husk	17
3	Sugarcane	Baggasse, tops, leaves	17
4	Maize	Straw, tops, leaves	11
5	Ground nut	Staw	4
6	Mustard seeds	Straw, husk	4
7	Coconut	Frond, husk, shell	4
8	Cotton	Straw, husk	4
9	Pulses	Straw, husk	2
10	Jute and mesta	Straw	2

3.3 Prospects of bioenergy plantation on wastelands

Wasteland in India is described as ''degraded land which can be brought under vegetative cover with reasonable effort (and cost), and which is currently under-utilized or land which is deteriorating for lack of appropriate water and soil management or on account of natural causes'' (NRSA 2005). The wastelands in India mainly belong to two categories, i.e. cultivable and non-cultivable. The cultivable wastelands comprise of various categories such as shifting cultivation areas, degraded forestland, degraded pastures and mining wastelands which can be brought under tree cover (NWDB 1986). There are many ambiguities about the area of wastelands in India. For instances, the National Remote Sensing Agency (NRSA) has estimated that there are about 55.27 million ha of wastelands in India (NRSA, 2005), whereas the National Wasteland Development Board has estimated an area of 123 million ha under

wastelands (ICAR 2010). Many interventions have been taken place to halt further degradation and rejuvenate these lands, particularly under Joint Forest Management program aiming to bring such land under tree cover. The IFS officers were asked to inform whether there was any wasteland in their area, which could be utilized for bioenergy plantations and if there was such land available what the present use of that land was. About 60% of the respondents considered that there were available wastelands in their area, whereas about 35% of the respondents considered that there was no wasteland available for bioenergy plantation in their area. Almost half of the respondents informed that most of the wastelands were occupied (mainly for human settlement and crop fields) and some were used for grazing **(Figure 4)**.

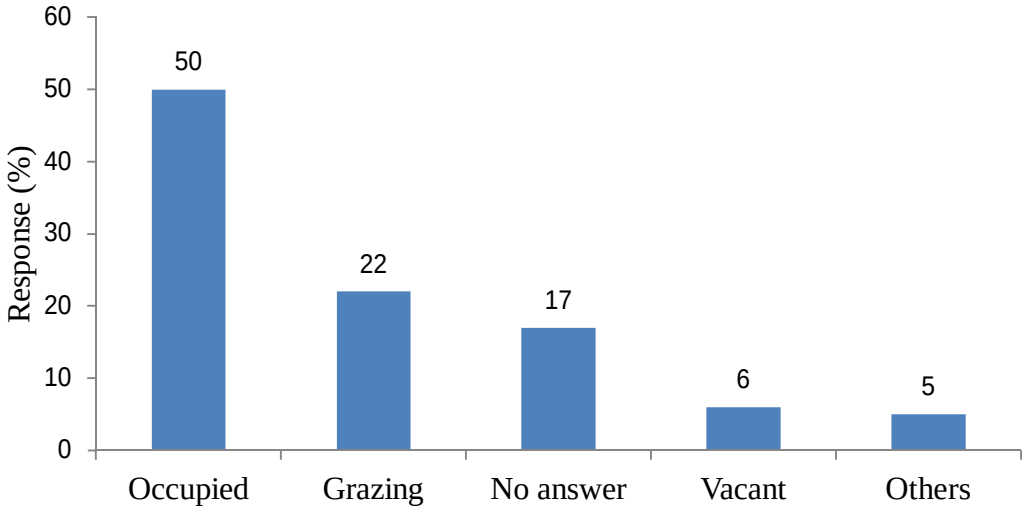

Figure 4. Respondents' answers on the present status of wastelands in their area.

The IFS officers were asked to provide names of three tree species, which would be promising for bioenergy plantation on wastelands. Based on their experiences, they selected some 25 tree species of which the top 3 promising tree species were *Acacia spp., Prosopis juliflora* and *Eucalyptus spp.* According to their opinion, the top 10 most promising tree species for energy wood plantation in wasteland are given in **Table 4.**

Table 4. Promising tree species for energy wood plantation in wasteland

No.	Name of tree species	Response (%)
1	*Acacia spp.*	70
2	*Prosopis juliflora*	51
3	*Eucalyptus spp.*	43
4	*Pongamia spp.*	20
5	*Leucaenia leucocephala*	20
6	*Populus spp.*	14
7	*Casuarina spp.*	14
8	*Jatropha curcas*	14
9	*Azadirachta indica*	12
10	*Alnus nepalensis*	8

The IFS officers were asked to provide their views on energy wood plantation on wastelands. About 95% of them supported the view that the energy wood plantation in wastelands was a relevant idea. They suggested that the energy wood plantation in wastelands could increase forest resources, improve supply of firewood and reduce the biotic pressure on the existing forest resources **(Table 5).** In addition, they perceived that raising energy wood plantations in wastelands could enhance the utilization of such lands, improve environmental quality and create job opportunities for local people. However, 5% of the respondents were not positive towards energy wood plantation in wastelands as they thought that such afforestation program could affect livelihood systems (e.g., grazing and cropping practices) of the local communities.

Table 5. Respondents' answers on the potential positive impacts of energy wood plantation in wastelands (multiple answers)

No.	Reason	Response (%)
1	Increase forest resources	90
2	Improve supply of firewood	66
3	Reduce pressure on existing forest resources	42
4	Proper utilization of land	42
5	Improve environment	39
6	Opportunities for employment and income	18

The IFS officers were asked whether there were any challenges in utilizing wastelands for energy wood plantations. About 83% of the respondents viewed that energy wood plantations in existing wastelands could be a challenging issue while 17% of the respondents did not provide any answer. However, the main challenges of utilization of wastelands for energy wood plantation were identified from the social perspectives (e.g., encroachment of wasteland for housing and agriculture). Other challenges identified were political influences, grazing, and controversy regarding land ownerships (**Figure 5)**. More than half of the respondents informed that energy wood plantations in wastelands would involve a great challenge since many wastelands had been encroached by the local people. It requires political willingness and cooperation from local communities, local government and the policy makers to alter the status. However, the respondents also considered that the energy wood plantations in wastelands could also have negative impacts on grazing as well as animal husbandry. Furthermore, they informed that controversy of land ownership was one of the challenges for the implementation of energy wood plantation programs in wastelands. The dispute on ownership of wasteland is a common phenomenon in many states of India i.e. Orissa and Madhya Pradesh (UNDP 2008), which is one of the major challenges for implementation of afforestation programs on such lands.

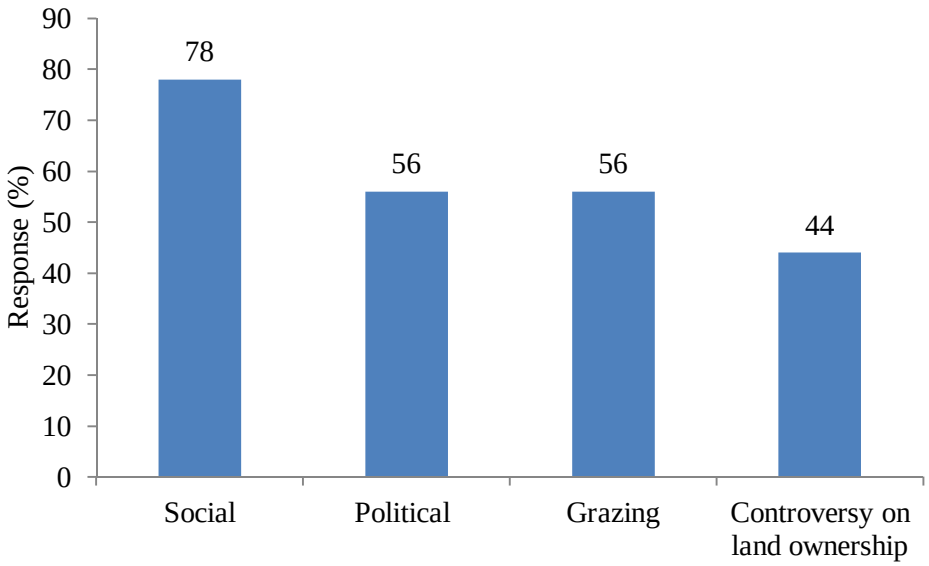

Figure 5. Respondents' answers to the possible challenges for raising energy wood plantations in wastelands (multiple answers).

3.4 IFS officers' perceptions of socio-cultural aspects of bioenergy promotion

3.4.1 Perceptions of local peoples' dependency on biomass resources and willingness of biomass supply to bioenergy plants.

In this section, the survey was extended to explore the IFS officers' perceptions of various socio-cultural perspectives of bioenergy promotion in India. The first six questions mainly focused to know the local peoples' dependency on the existing biomass resources and their willingness to supply biomass to bioenergy production plants **(Table 5)**. It appeared that the dependency on existing forest resources for fuelwood, especially for cooking fuel and heating purposes, was quite high (Item 1), whereas the dependency on crop residues for the same purposes was medium (Item 2). It indicated that woodfuel dominated in overall biomass fuel consumption. It is quite evident that the local people have had a high level of willingness to plant trees on wastelands (Item 5) rather than other government (Item 4) and privately owned lands (Item 3). The results also indicated that the local people were interested in using their land more for crop cultivation than for tree planting (Item question no.6).

Table 5. Respondents' perceptions on local peoples' dependency on biomass resources and their willingness to plant trees on different lands

Item question no.	Response (%)			
	High	Medium	Low	Don't know
1. What is the dependency among local people on the use of fuelwood for cooking and heating in your area?	76	10	14	0
2. What is the dependency among local people on agricultural residues for meeting their energy demand in your area?	28	33	29	10

3. What do you think about local people's willingness to plant trees on their lands for meeting their fuelwood demand?	14	19	67	0
4. What do you think about local people's willingness to plant trees on government lands (not wasteland) for meeting their fuel wood demand?	19	47	29	5
5. What do you think about local people's willingness to plant trees on wastelands for meeting their fuelwood demand?	48	28	14	10
6. What do you think about local people's willingness to cultivate agricultural crops for meeting their energy demand?	10	10	70	10

3.4.2 IFS officers' perceptions of local peoples' attitudes towards bioenergy promotion

Forestry experts' opinions are considered as an important element for bioenergy development in many developed and developing countries (Halder et al. 2010; Qu et al. 2012; Gautam et al. 2013). Hence, the IFS officers were asked a set of questions related to the local peoples' attitudes towards bioenergy promotion **(Table 6)**. The results revealed that the existence of bioenergy plant may have had influence on local people's attitudes towards bioenergy resources development and bioenergy market development. Nearly half of the respondents indicated that the existence of bioenergy plant could influence the local people for planting trees on their own lands (Item question no. 1 of Table 6). It appeared from the respondents' perceptions that local people were not interested in planting trees on their lands (Item question no. 3 of Table 5); however, they also perceived that the existence of a local bioenergy plant could motivate local people to plant trees on their lands (Item question no. 1 of Table 6). Such attitudinal change could emerge due to the existence of a bioenergy plant, which could provide assurance to the local people for buying energy wood from their plantations. It is obvious that farmers always look for competitive markets for selling their products, and for biomass fuel it is more important since it is a non-food material. Therefore, selling of biomass fuels always involves uncertainty. The existence of farming contracts could help in removing such uncertainty and it could increase understanding between the farmers and the consumers. However, about three quarters of the respondents informed that there was no such contract farming existing in their region (Item question no.2 of Table 6). Respondents from Karnataka and Kerala informed that there were some contracts existing between the farmers and biomass plant operators.

The majority of the respondents suggested, however, that the introduction of farming contracts could enhance and ensure the supply of feedstock to the bioenergy plants (Item 1). One of the mechanisms of such farming contracts could be the Joint Forest Management, which is commonly practiced in many parts of India for enhancing tree resources in degraded forest lands through 'co-management' between the local people and forest department (Balooni and Singh 2007). Over 90% of the respondents considered that such a mechanism could be a useful tool for motivating farmers for energy wood plantation on public forest

lands (Item question no.4 of Table 6). Nonetheless, the majority of the respondents viewed that the existence of bioenergy plants could also influence the local farmers to sell their forest products and crop residues to the bioenergy plants (Item question no. 5 and 6 respectively). However, the results indicated that the presence of bioenergy plants could greatly influence the local farmers' attitudes towards producing and supplying both forest and agricultural biomasses for bioenergy producers.

Table 6. Respondents' perceptions of local peoples' attitudes towards bioenergy promotion

Item question no.	Response (%)		
	Yes	No	Don't know
1. Do you think the local people will be willing to plant trees on their own lands for supplying energy wood to a local bioenergy plant?	45	30	25
2. Is there any farming contract between farmers and a company (e.g. pulp and paper mills) in your area?	25	70	5
3. Do you think the supply of biomass from forest plantations can be secured through contract farming in your region?	65	20	15
4. Do you think participatory forest management practices (e.g., Joint Forest Management) can be useful for motivating local people for energy wood plantations on public forest lands?	91	9	0
5. Do you think that the local people are willing to sale forest products i.e. fuelwood to a bioenergy production plant?	63	27	10
6. Do you think that the local people are willing to sell their crop residues to a bioenergy production plant?	60	20	20

3.4.3 IFS officers' perceptions of bioenergy markets

Development of market is considered as an important element for promoting bioenergy (Hillring 1997; Olsson et al. 2012). The IFS officers were asked whether there were markets in their area where the local people could sell their forest products and crop residues. About 62% of the respondents informed that there were markets existing in their area where the local people could sell their woodfuels. However, about 60% of the respondents informed that there were no markets in their area for selling crop residues. This indicates that crop biomass-based markets have not been developed. The small-scale commercial enterprises are the main buyers followed by individual households for both wood-based and non-wood based biomass (crop residues and animal dung). About two-third of the respondents informed that women mainly brought both wood-based and non-wood based (crop residues and animal dung) biomass fuels to the local markets for selling.

The IFS officers were asked whether middlemen existed in the local trade of fuelwood and crop residues. About half of the respondents informed that there were middlemen involved in the trade of both fuelwood and crop residues in their areas. About 30% of them informed that there were no middlemen involved in the local trade of biomass fuels as the farmers would

sell their products directly to the buyers. However, 20% of the respondents did not give any answer about the involvement of middlemen in the trade of biomass fuels. The respondents informed that the average price of woodfuel and crop residues (residues from cereals) were about 4310 Indian Rupees/ton (~€52/ton) and 3290 Indian Rupees/ton (~€40/ton), respectively. However, the market price for both woodfuels and crop residues fluctuates following the principle of demand and.

3.4.4 IFS officers' perceptions of promoting bioenergy production from municipal wastes

In this section, the IFS officers were asked to inform the feasibility for exploitation of municipal wastes for bioenergy production. About two-third of the respondents informed that there were municipalities in their area, where wastes were available for utilizing in energy production purposes. About 20% of them informed that there was a municipality in their area; however, the amount of generated waste was not enough to commercially produce energy from it. Regarding the current management of municipal waste, about 78% of the respondents informed that the wastes were mainly dumped in the dumping sites, whereas about 10% of them informed that the wastes were burnt openly in the dumping site. Nearly 12% of them informed that valuable recycling materials (i.e. plastic, rubber and metal) were collected from municipal wastes before final dumping. About 53% of the respondents informed that there were some people involved in the collection of recyclable materials from the waste. The collectors mainly collect recyclable materials from the dumping sites and sell them to the local markets. The collection of recyclables is the main source of livelihoods for the waste collectors. The dependency of waste resources for local people's livelihood has been reported in most of the cities in India and other Asian countries (APO 2007).

3.4.5 IFS officers' perceptions of technological development of bioenergy

In this section, the items explored the IFS officers' perception of various aspects related to technological development for bioenergy promotion. About 46% of the respondents suggested that biogas would be the most suitable technology for bioenergy promotion in Indian context, while about 27% of them supported CHP (combined heat and power) plans, and about 14% suggested liquid bio-fuels (i.e. bioethanol and bio-diesel). About 73% of the respondents viewed that the installation of biomass-based energy plants would be possible in their area **(Figure 6)**. Only 9% of them did not consider the possibility for such installations in their area due to insufficient supply of feedstock. Nonetheless, the IFS officers were asked to select the most important biomass, which was the most suitable and ready for producing bioenergy. Based on their selection, the most available biomasses for bioenergy production in the context of technological maturity were municipal waste (52% of the respondents ranked 1st), crop residues (23% ranked 1st), forest biomass (14% ranked 1st), and agro-industrial residues (10% ranked 1st).

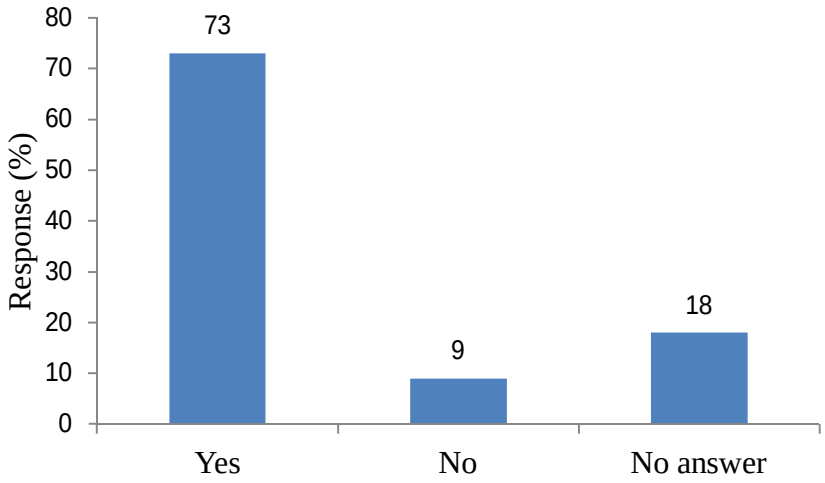

Figure 6. Respondents' answers whether there is a possibility of the installation of biomass based energy plant in their area.

Modernization of biomass for energy use in India involves a number of challenges from technological, environmental and socio-economic aspects (Shukla 1997). The modern biomass technologies offer possibilities to convert biomass into synthetic gaseous or liquid fuels (i.e. bioethanol, biomethanol) and electricity. In these regards, the IFS officers were asked to select the most challenging issues, which would impede bioenergy promotion in India. From the perspective of biomass supply, the lack of harvesting technology was identified as the main challenge followed by the lack of suitable terminals for storage of biomass **(Table 7)**. However, the lack of appropriate biomass conversion technology and the lack of bioenergy market had been identified as the major challenges to the penetration of modern biomass technologies. Therefore, formulation of technology push policies was emphasized, which could be substituted or augmented by market pull policies (Shukla 1997).

Table 7. Challenges involved in the modernization of biomass for energy use in India

A. Challenges related to supply of biomass	Response (%)
Lack of harvesting technology	62
Lack of terminals for storing biomass	12
Lack of suitable railway network for transportation	7
Lack of proper road network	5
Lack of highways for fast transporting biomass	5
Lack of logistics for transporting of biomass	5
No answer	5
B. Challenges related to technological conversion of biomass	
Lack of biomass conversion technologies	43
Lack of related research and development	29
Lack of industrial scale bioenergy plants	14
Lack of related research and development	5
Other	5
No answer	5
C. Challenges related to distribution of bioenergy	
Lack of marketing	48

Lack of distribution mechanisms of heat and power (CHP) produced from biomass	33
Lack of grid connection in rural area	5
Maintenance of existing power grids	5
Motor engines not ready for using biofuels	5
No answer	5

3.4.6 IFS officers' perceptions on the prospects of development of bioenergy in India

In India, bioenergy is playing a significant role for providing a number of benefits to the society, particularly in energy security and poverty reduction in rural areas of the country (TERI 2010). In this regard, the IFS officers were asked to provide information about the possible benefits that could be received by local people from biomass-based energy plants. Almost all respondents informed that the most benefit that could be derived from biomass-based plants would be for providing clean energy. Other possible benefits were identified as creation of jobs, improvement of environmental quality and reduction of pressure on existing biomass resources **(Figure 7)**.

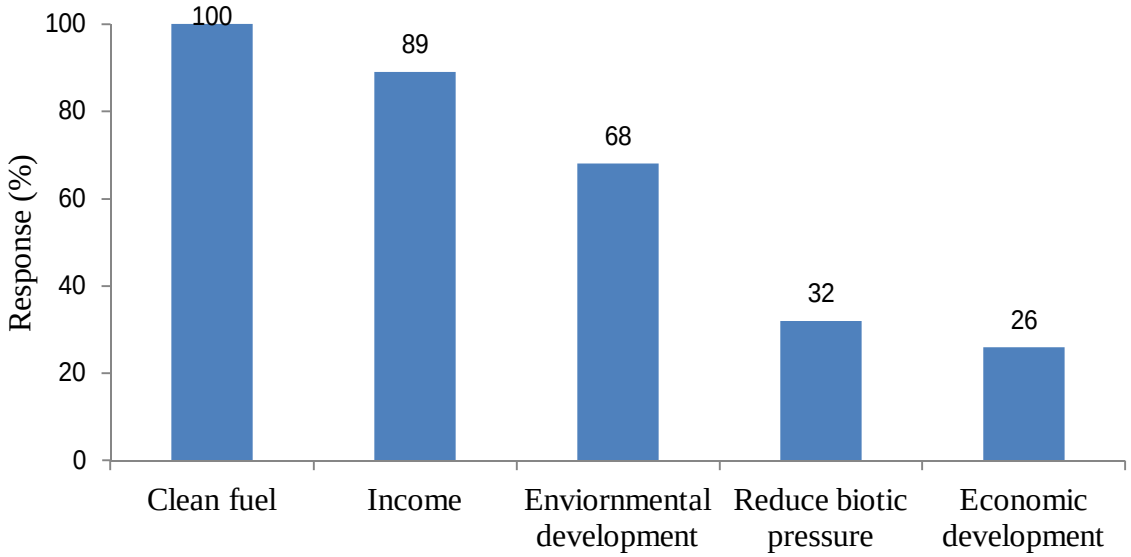

Figure 7. Respondents' answers on the possible benefits of bioenergy plants (multiple answers).

India has a high potential for developing biomass-based energy programme interventions (MSSRF 2011). The potential of biomass-based power generation installation capacity is estimated as 16000 MW (TERI 2010; IEA 2012) and by the end of .2011 only 2788 MW was commissioned, which is 17.5% of the total biomass-based power installation capacity of the country (Ministry of Power 2012). However, the IFS officers were asked to give their view on the prospects of biomass-based energy production in India. About 76% of the respondents viewed that biomass-based small-scale power generation plants would have the greatest prospect while only 19% of the respondents supported for large-scale biomass-based power plants.

4. CNCLUSIONS

India, being a tropical country, has large potential for energy generation from forest biomass, crop residues and municipal wastes. Although biomass potential from forests for bioenergy production is presently quite low, it can be substantially increased through several interventions such as implementation of afforestation programs in both private and public lands. Utilization of wastelands for energy plantation, selection of suitable tree species that could enhance biomass productivity, economic operations of plantations, improvement in logistics and infrastructure are critical areas which shall determine the future of forest-based bioenergy production in India. However, the survey revealed that the biomass potential from crop residues would be quite promising. Therefore, there is a need to undertake studies on investigating the promising crop areas, suitable cropping patterns, current utilization of crop residues, and willingness of farmers to sell their crop residues for bioenergy production. It is also important to conduct studies on the sustainability aspects of supplying biomass feedstock, utilization of the resources, land-use policies and livelihood of the local communities. Moreover, land utilization for large-scale plantation programmes and other biomass feedstock production should be followed on accordance of international guidelines, in order to ensure that such practices will not bring negative impacts on food production systems, livelihood, and biodiversity. In addition, GHG calculations of bioenergy, fossil fuel/fertilizer inputs in bioenergy production and downstream processing should also be taken into account while planning for biomass energy plant.

The study revealed that there are a number of challenges in the development of biomass-based energy production in India. Lack of societal awareness, small land holdings, pastures on wasteland, lack of market for biomass fuel products, lack of adequate governmental policies on land management, and lack of appropriate bioenergy technologies and good could be the limiting factors for promoting biomass-based energy production in the country. Moreover, the lack of biomass energy market has been considered as one of the primary barriers to the penetration of modern biomass technologies. In this regard, policies related to various aspects of bioenergy are needed to be analyzed consistently, which could provide guidelines for augmentation of bioenergy market strategies. It is important to note that the IFS officers participating in this present survey provided worthy information for the development of biomass-based energy plants in India but due to the limited number of respondents the information presented here needs to be viewed with caution. Further comprehensive stakeholders' survey on bioenergy promotion is therefore recommended, which could provide better understanding on various aspects of challenges and opportunities related to the planning and development of biomass-based energy projects in India.

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