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Article

Benefits and Challenges Associated with the Development of Forest-Based Bioenergy Projects in India: Results from an Expert Survey

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Abstract: Development of energy systems, based on forest biomass, is a challenging issue in India. The study investigated perceptions of fifty-five Indian Forest Service (IFS) officers in relation to the potential benefits and challenges associated with the development of forest-based bioenergy (FBE) projects in India when they participated in two training programs in Finland during 2010. They generally agreed that development of FBE projects could have beneficial impacts on job creation, income generation, rural development, and restoring ecological degradation. They perceived lack of public acceptance and political support, impacts on biodiversity, and lack of technologies and infrastructure as the considerable challenges to the development of FBE projects in India. The study could provide some policy directions towards developing the FBE sector in India. It recommends conducting further studies to include a larger group of experts and other stakeholders to investigate the broader societal perceptions of FBE projects in India. In addition, the study also recommends building the capacity of the IFS officers so that they can play a key role from the government side for developing the FBE sector in the country.

Keywords: bioenergy; forests; benefits; challenges; India; experts; perceptions

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1. Introduction

India's population, of over a billion, and rapid economic growth have led to an increasing demand for energy and dependency on imported oil from foreign countries. 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. Despite the country's fast economic growth in recent years, the major share of India's rural population still remains "energy poor" [1]. The latest estimate shows that approximately 24% (*ca.* 289 million) of India's population do not have electricity access and 70% (*ca.* 836 million) rely on traditional biomass for cooking [2]. There is also a very large gap between rural and urban households in the country, which depend on traditional biomass for cooking and heating (e.g., 90% dependency in rural areas compared to 22% in urban areas) [3].

Like other major developing economies, such as Brazil and China, India has also taken steps to increase the production of domestic biofuels (ethanol and bio-diesel) for addressing climate change and energy security related concerns [4]. The Government of India (GoI) has formulated several policies since 2003 in order to increase the domestic production of liquid biofuels. Among the most recent policies, the GoI adopted an ambitious *National Policy on Biofuels*, in 2009, targeting a 20% blend of biofuels with gasoline and diesel by 2017 [5]. However, the *National Policy on Biofuels* does not mention specifically the role of forest biomass for energy production and, thus, it is difficult to anticipate the future development of this sector in the country.

Presently, the most common feedstock for bioenergy can be categorized according to its origin, such as forestry biomass, agricultural biomass, and waste-based biomass (e.g., municipal organic wastes). Within that forestry biomass used in energy production (referred throughout this paper as forest-based bioenergy or FBE), a wide range of biomass types can be used. It generally includes small diameter wood and logging residues (e.g., branches, stumps, and stems from thinning), dedicated energy wood plantations (e.g., fast growing species, such as willow and poplar), and forest industry residues (e.g., black liquor and bark). In all cases, FBE appears to be an environmentally friendly alternative to fossil fuels and, thus, its development is favored through various policies in many countries [6].

There are not many studies related to the opportunities and challenges associated with bioenergy production in India from environmental and socio-economic perspectives. 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 developed in India [7]. In this context, Das and Priess [8] have reported various challenges for developing large-scale bioenergy projects in India. According to them, one of the major challenges is the lack of actual availability and difficulty in the acquisition of wastelands for energy crop plantations. It is due to the reason that landless and indigenous peoples in the country may have already used a large proportion of such land for the purposes of habitation, grazing, and agricultural production [8]. The other challenges that have been identified by Das and Priess [8] are the 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. Therefore, there is not much scientific information

available about the potential of forest biomass for bioenergy production in India from socio-economic, ecological, or technological perspectives.

Although there are not many studies available on stakeholders' perceptions and attitudes concerning energy production from forest biomass in an Indian context, internationally there are a growing number of such studies available and most of them have been conducted in Europe, North America, and other Asian countries [9]. Unlike in India, the share of privately owned forests is significant in both Europe and North America. Small-scale private forest owners (also known as non-industrial private forest owners, or NIPFs) play a major role in supplying forest biomass to the forest-based industries including the bioenergy industry in Finland, Sweden, and the US. Halder *et al*. [10] conducted a study among the NIPFs in Finland to explore their perceptions of energy wood supply from their forests. The results showed that the Finnish NIPFs perceived the price of energy wood as the most important factor for them to decide if they supply energy wood from their forest estates and, since price of energy wood was not very attractive to them, they were not motivated to supply energy wood from their forest estates. Rämö *et al*. [11] also found that the Finnish NIPFs perceived price and market information as critical factors for harvesting energy wood from their forest estates. Their study also revealed that the Finnish NIPFs were concerned over the loss of soil fertility due to excessive harvesting of energy wood.

In Sweden, Bohlin and Roos [12] found that the Swedish NIPFs did not perceive price as the deciding factor for them to harvest energy wood from their forest estates whereas they sold fuel wood mainly to get rid of the debris that accumulated on the forest soil during the harvesting operations. However, the Swedish NIPFs also appeared to be concerned over the loss of soil nutrients due to harvesting of energy wood and as a result of that many of them refrained from selling energy wood. In comparison to the NIPFs in Finland and Sweden, NIPFs in the US appeared to be positive about harvest and supply of energy wood from their forest estates [13–16]. However, some of the barriers that the NIPFs in the US perceived affecting the energy wood harvest and supply were lack of a ready market and lack of efficient logistics for transporting biomass over long distances [15].

In addition to the private land owners' perceptions of FBE, a number of studies have explored experts' perceptions of FBE in China, Nepal, and the US. In a study from Nepal Gautam *et al*. [17] found that the Nepalese state forestry professionals were very positive about the potential socio-economic and environmental benefits that the FBE projects could bring in Nepal, such as reviving rural economy by generating new incomes and improving forest management practices. Qu *et al*. [18,19] conducted a study among Chinese academia and state forestry professionals to explore their perceptions of forest-based bioenergy development in China and they revealed that the Chinese experts perceived the potential for bioenergy as low in China compared to other renewable energy sources due to the scattered forestry biomass resources in the country, lack of national and international standards in FBE production, and the absence of a domestic FBE industry. In the US, Dwivedi and Alavalapati [20] found that the experts from academia, government, and industry perceived FBE positively in terms of its contributions towards achieving energy security and improving local economy. However, their study also revealed that the experts perceived long-term supply of forest biomass from public forests to mill gates as a challenge due to high logging and transportation costs.

The development of large-scale FBE projects is a challenging issue as it involves several policy sectors such as agriculture, forestry, energy, economy, water, and environment [21]. As there has not been any study that explored experts' perceptions of FBE in an Indian context, a critical knowledge gap exists and that makes decision-making for large-scale FBE projects in the country more complex and challenging compared to the deployment of other renewable energy technologies, such as solar and wind. There have been several controversies regarding bioenergy production all over the world for its negative impacts on socio-economic and environmental conditions [22]. Lessons learned from those projects indicate that societal perceptions are a significant factor that should be well understood before developing FBE projects. Without an understanding of the social dimensions of the modern bioenergy technologies, conflicts could occur in various places and among different stakeholders, such as between local communities and bioenergy developers [23,24].

In India, forests cover 20% (68 million ha) of the land area and the Ministry of Environment & Forests (MoEF) under the GoI is the nodal agency for planning, promoting, coordinating, and implementing the forestry and environment related programs. The MoEF recruits various types of professionals to manage India's forest resources. Among them, professionals recruited by the MoEF through the Indian Forest Service (referred throughout the paper as IFS officers) examinations are posted across the whole country and they play key managerial and administrative roles in implementing governmental policies in forest areas under their jurisdictions. In an Indian context, these IFS officers can be considered as experts in providing information to the policy makers on various local issues, such as socio-economic conditions of the local people, revenue generation from forests, anthropogenic pressure on forests, and local communities' dependency on fuel wood. This information can be regarded as first level background information for developing FBE projects in different parts of the country and it, thus, has policy relevance.

It is worth mentioning here that the IFS officers are not the only professionals in India for assessing the scope of FBE projects as there are many other professionals working in research institutions, industry, and non-governmental organizations on issues related to bioenergy. In addition, local communities and politicians also appear to be important stakeholders of any large-scale FBE project in the country. Therefore, broader public consultations need to include all these professionals and stakeholders before arriving at any conclusions regarding the scope of FBE projects in an Indian context. However, such a broad stakeholder consultation was beyond the scope of the present study. Therefore, the study can be best regarded as a case study that aimed to explore IFS officers' perceptions of FBE in India. Nevertheless, the study also aimed to provide some recommendations for developing future FBE projects in the country.

2. Method and Data

The study conducted a questionnaire-based survey among a group of IFS officers who participated in forestry training programs in Finland. The MoEF under the GoI and the School of Forest Sciences under the University of Eastern Finland organized those training programs. The main objective of the training program was to provide the IFS officers training and exposure regarding forest management, climate change, and bioenergy in an international environment. The other broad objective was to expand the international cooperation in the forestry sector between

India and Finland [25]. The survey was conducted among fifty-five IFS officers (N = 55). The study did not suffer from any non-response bias and all the participants in the study were male. It is worth mentioning here that the IFS cadre has 2000 officers working in India including those who have just 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. It is the last category alone in the IFS which deals with policy matters and the rest are exclusively in the category of implementers. The survey covered only 3% of the total number of IFS officers and 92% of them belonged to the middle level category with 10–20 years of working experience in the IFS cadre.

A questionnaire was developed using consistent items within two sections. The *first* section included items related to the respondents' educational and work related profiles, as well as information on the status of forests and local socio-economic conditions in their work areas. The *second* section consisted of an eighteen-item five-point Likert-type scale (*strongly agree* to *strongly disagree*) that explored the respondents' perceptions of the potential benefits and challenges related to the development of FBE projects in India. The items on the Likert-type scale were selected after a comprehensive literature review and expert consultations.

A few bioenergy experts in both Finland and India received an initial form of the questionnaire and they suggested some improvements for the final version of the instrument. This helped to improve the content relevance of the survey instrument. The paper version of the questionnaire was administered to the IFS officers during their training sessions. They returned the completed questionnaires to a training facilitator and, on average, they took 25 minutes to complete the survey. The respondents were not provided any incentive to participate in the survey. The reliability analysis for the opportunities and challenges scales showed adequate level of internal consistencies as Cronbach's alpha values were 0.83 and 0.68, respectively. The quantitative analysis was performed by using SPSS 19.0 program. No statistically significant differences were found related to the respondents' perceptions of the opportunities and challenges of FBE projects. Therefore, it was not reported in the study. Both parametric and non-parametric methods were tried to find out any significant differences but no differences appeared. The complete survey instrument can be obtained by requesting the corresponding author.

3. Results

3.1. Status of Forests and Local Socio-economic Conditions in the Respondents' Work Places

The majority of the IFS officers reported that they did not have any training or working experiences with bioenergy related projects (Table 1). The majority of them were posted in the eastern and northern states of India (Table 2). About 73% of the respondents did not consider forests under their jurisdictions as a major source of revenue to the local forest departments as well as to the local communities. About 67% of the respondents informed that the areas under their jurisdictions belonged to the economically poor regions of the country and local communities were highly dependent on agriculture for their livelihoods. About half of the respondents reported that the dependency of local people on fuel wood collection from forests was very high whereas the remaining half of the respondents reported it to be moderate or low.

Table 1. Respondents' educational and work related profiles (N = 55).

Profile of the Respondents	
Age	Mean: 48.35 years (SD = 5.7)
Educational qualification	Bachelor: 20%; Master: 78%; Doctoral: 2%
Service years as an IFS official	10–20 years: 92%; Over 20 years: 8%
Participation in bioenergy related training programs while in service	Yes: 25%; No: 75%
Experience with working in bioenergy projects in India	Yes: 22%; No: 78%
Location of the job posting in the county	North: 23%; South: 10%; East: 33%; West: 17%; Central : 17%

Table 2. Status of forests and local area conditions in the respondents' work places (N = 55).

Forest and local area profiles	
Income from forests to the local Forest Department	High: 27%; Low: 73%
Main sources of income to local people	Agriculture: 73%; Industry & others: 25%; Forestry: 2%
Dependency on fuel wood among local people	High: 51%; Moderate: 34%; Low: 15%
Economic status of the area	Poor: 67%; Economically developed: 33%

3.2. Respondents' Perceptions of the Potential Benefits from FBE Projects in India

In this section, the items explored the IFS officers' perceptions of the benefits that could emerge from developing FBE projects in India (Table 3). In terms of socio-economic benefits, the items focused on the issues of job creation, income generation to forest departments, and benefits to rural areas. It appeared that the majority of the respondents had positive perceptions of FBE related to its potential contribution to these socio-economic aspects. Among all potential benefits of a FBE project, its contribution towards creating new jobs (*Item 1*) in the country was agreed most positively by the respondents. The other benefits of FBE projects that were perceived very positively by the respondents were rural development (*Item 2*), revenue generation for local forest departments (*Item 4*), reducing land degradation (*Item 5*) and soil erosion (*Item 3*), and providing energy security (*Item 6*). More than half of the respondents agreed that FBE projects could contribute to sustainable forest management (*Item 8*) and reduce emissions of greenhouse gases (*Item 7*). Nevertheless, they were much lower than the respondents who agreed to the potential benefits listed under *Items 1–6*. Similarly, there was no strong agreement among the respondents regarding FBE project's contribution towards improving forest health in India (*Item 9*).

3.3. Respondents' Perceptions of the Potential Challenges towards Developing FBE Projects in India

The items in this section assessed the respondents' perceptions of the potential challenges that FBE projects could face in India. The nine items included financial, socio-political, technological, and environmental issues relevant in an Indian context (Table 4). Among all the challenges, lack good practice guidelines (*Item 10*) and lack of technology (*Item 11*) emerged as the mostly agreed challenges by the respondents. It appeared that the respondents from the northern and eastern regions were most concerned with those two mostly agreed challenges. More than two-thirds of the

respondents agreed that the lack of political support for FBE projects (Item 12), high level of public investment (*Item 13*), and lack of infrastructure (*Item 14*) could be the limiting factors for such projects in India.

Table 3. Respondents' perceptions of the potential benefits from forest-based bioenergy (FBE) projects in India (N = 55).

Items	**Agreement (%)**	**Disagreement (%)**	**Neutral (%)**
1. Bioenergy production from forests can create new jobs in India (*Mean = 4.22, SD = 0.809*)	91	7	2
2. Rural areas in India can benefit more from forest-based bioenergy production than urban areas (*Mean = 4.20, SD = 0.678*)	89	2	9
3. Energy wood plantations can reduce soil erosion in India (*Mean = 4.21, SD = 0.776*)	86	4	10
4. Bioenergy production from forests can be an additional source of income to the Forest Departments (*Mean = 4.09, SD = 0.917*)	85	11	4
5. Energy wood plantations can reduce land degradation in India (*Mean = 4.19, SD = 0.848*)	85	7	8
6. Bioenergy production from forests can help to achieve energy security for India (*Mean = 3.91, SD = 1.005*)	76	13	11
7. Best practice use of forest biomass for energy production can cut greenhouse gases emissions of that energy use to almost neutral (*Mean = 3.58, SD = 1.196*)	59	16	25
8. Sustainable forest management can be promoted through forest-based energy production in India (*Mean = 3.58, SD = 1.083*)	55	18	27
9. Harvesting biomass from forests for energy production can improve the health of forests in India (*Mean = 3.33, SD = 1.064*)	48	24	28

Notes: Agreement has been measured by combining responses under Strongly Agree and Agree; Disagreement has been measured by combining responses under Strongly Disagree and Disagree. The coding was done as Strongly agree = 5, Agree = 4, Neutral = 3, Disagree = 2, and Strongly disagree = 1.

More than half of the respondents agreed that initiating large-scale FBE projects could be affected by the government's effort to protect India's biodiversity (*Item 15*) and low public acceptability for such projects (*Item 16*). In terms of the costs of developing FBE projects compared to other renewables and fossil fuel based energy systems (*Items 17–18*), the respondents did not show any clear perceptions (neither strong agreement nor disagreement) and almost one-third of them preferred to remain neutral on these issues. In general, it appeared that the respondents did not agree that FBE projects would be more expensive than other renewable and fossil fuel based energy systems.

4. Discussion

The study investigated perceptions of the IFS officers related to the potential benefits and challenges associated with the development of FBE projects in India. The study was conducted during the IFS officers' training programs in Finland in 2010. The results showed that the respondents had quite similar perceptions of the potential benefits and challenges associated with the development of FBE projects. Such similar perceptions perhaps emerged due to an almost non-existing FBE sector in

the country and thus no clear positive or negative impacts of such projects were visible to the respondents to influence their perceptions. In general, while the respondents perceived that there would be some potential benefits from the development of FBE projects in India, they also agreed that there would be several challenges for implementing such projects. It should be mentioned here that, though the IFS officers came from different geographical locations within India, their perceptions of forests and socio-economic conditions in their work places did not differ much. In other words, a high dependency among local communities on agriculture and collecting fuel wood from forests for cooking and heating; poor economic conditions of the surrounding areas where forests are located; and low revenue generated from forests to local forest departments depicted a dismal picture of the country's forests and the socio-economic conditions of the forest-dependent communities. These factors could have been the reasons that the study did not find much difference in the IFS officers' perceptions of the potential benefits and challenges related to developing FBE projects in India.

Table 4. Respondents' perceptions of the potential challenges of forest-based bioenergy (FBE) projects in India (N = 55)

Items	**Agreement (%)**	**Disagreement (%)**	**Neutral (%)**
10. Lack of good practice guidelines for whole cycle (collection to processing and use) can limit the large-scale use of forest biomass for energy production in India (*Mean = 3.96, SD = 0.637*)	85	4	11
11. Technology has not yet been developed that can allow efficient use of forest biomass as a source of bioenergy in India (*Mean = 3.93, SD = 0.813*)	82	9	9
12. Lack of political support can limit large-scale use of forest biomass for bioenergy production in India (*Mean = 3.81, SD = 0.892*)	69	9	22
13. Large-scale use of forest biomass for bioenergy production requires high level of investment from the Indian government (*Mean = 3.62, SD = 0.850*)	67	15	18
14. Problems related to infrastructure can limit large-scale use of forest biomass for bioenergy production in India (*Mean = 3.52, SD = 0.885*)	67	20	13
15. Pressure to protect biodiversity can limit the development of large-scale use of forest biomass for bioenergy production in India (*Mean = 3.40, SD = 1.196*)	63	33	4
16. Low public acceptability can limit large-scale use of forest biomass for bioenergy production in India (*Mean = 3.45, SD = 0.878*)	57	18	25
17. Bioenergy production from forests can be more expensive than producing energy from other renewable energy sources (*Mean = 2.94, SD = 0.940*)	33	37	30
18. Bioenergy production from forests can be more expensive than producing energy from fossil fuels (*Mean = 2.85, SD = 1.008*)	27	42	31

Notes: Agreement has been measured by combining responses under Strongly Agree and Agree; Disagreement has been measured by combining responses under Strongly Disagree and Disagree. The coding was done as Strongly agree = 5, Agree = 4, Neutral = 3, Disagree = 2, and Strongly disagree = 1.

The study focused on only one of the possible sources of bioenergy production in India. To be more comprehensive, possible future surveys of stakeholder perceptions should include a number of additional items that were not included in this study. For example, perceptions of agricultural and waste-based residues may differ from those of forestry-based bioenergy. The respondents held positive perceptions of FBE for its potential role in job creation, income generation, rural development, and improving energy security. However, the GoI has no dedicated policy for FBE and this leads to much uncertainty over the future of FBE projects in India. Additionally, in India where forests are primarily managed for their protection and conservation purposes, development of energy systems based on forest biomass will be contentious. The majority of the IFS officers in this study perceived that FBE projects could contribute towards sustainable forest management in India but not to improved forest health, which seemed to be contradictory. However, forest productivity is very low in India compared to the world average and large forest areas are also degraded due to various biotic and abiotic factors. Therefore, the respondents might have thought that the FBE projects could contribute towards social and economic development in the country and, thus, towards sustainable development; however, not towards improving the ecological conditions of forests. Apart from the findings from the study, there are unexplored issues related to land tenure, forest management, and institutional mechanisms that could affect the future plans for developing FBE projects in the country. Therefore, these issues should also be addressed in future studies of stakeholders' perceptions of FBE projects in India.

The study was among the first studies that explored the Indian state forestry professionals' (or the so-called experts) perceptions of FBE in an Indian context. Although there have been studies in Europe and North America that investigated private land owners' perceptions of FBE (see [10–16]), their relevance in India is limited as private forest ownership is negligible in the country. Therefore, the studies conducted in Nepal and China to explore state forestry professionals' perceptions of energy production from forest biomass (see [17–19]) could be more relevant in an Indian context due to the similar type of dominating public forest ownership that exists in these countries. Nevertheless, it can be said that the bioenergy experts in both developing and developed countries appear to have broader consensus in their perceptions of the potential benefits and challenges associated with bioenergy projects. For example, experts in the US appeared to have positive perceptions of bioenergy in terms of its potential contributions towards achieving energy security, creating jobs, and replacing fossil fuels (see [20,26,27]). At the same time, they perceive that the long-term supply of forest biomass from public forests, lack of suitable conversion technologies, competition from other renewable energy technologies, and increasing cost of forest biomass harvesting and transportation would be major challenges against developing FBE projects in the US. The state forestry professionals' perceptions of FBE in China, Nepal, and India also appear to be very similar. On one hand, they are positive about the potential benefits that FBE projects could bring in their countries, such as improvement of rural economy and creation of new jobs. On the other hand, they were concerned that the lack technology and infrastructure could be the limiting factors for developing such projects. Therefore, these findings seem to be relevant as they provide a broader picture of the pre-conditions that should be developed for implementing viable FBE projects in both developing and developed countries.

The study provided some directions for the government and private organizations that would be interested in developing FBE projects in India. In terms of policy relevance of the study, development of country specific FBE related technologies is essential and in the absence of a FBE sector in India, collaboration with technology providers from abroad should be considered. In addition, country-specific good practice guidelines for the whole value chain for FBE projects should be developed. There will be also a need for evaluating the broad public and political acceptance of FBE projects as these challenges were rated very high, even if not the highest by the IFS officers. Another important policy related measure that should be implemented is capacity building among the IFS officers for them to play an important role in developing future FBE projects in India. The findings of this case study showed that the majority of the IFS officers neither had any training nor working experiences related to bioenergy. Therefore, more training courses organized for them could inform them about the modern practices of bioenergy production from forest biomass that are sustainable and can contribute to the socio-economic developments in the country.

5. Conclusions

Development of future energy systems based on forest biomass is a challenging issue in India though such energy systems could provide energy security and other environmental and socio-economic benefits. However, a lack of related technologies and good practice guidelines could be the limiting factors for such project to take off soon in India. Therefore, the techno-economic, societal, and environmental concerns over FBE projects perceived by the IFS officers should be taken into account in order to make those projects viable. The FBE sector is still non-existent in the country though the dependency of rural people on forest biomass for cooking and heating is among the highest in the world. Therefore, meeting the basic energy demand of those people is a primary challenge for the country's policy makers. In this regard, highly motivated IFS officers with relevant FBE related knowledge and expertise could play a meaningful role in promoting such projects to address the renewable energy challenges in India. However, in addition to the IFS officers, for obtaining more comprehensive information on FBE other stakeholders and experts should also be invited in future studies to evaluate the benefits and challenges of such projects in India.

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Author Contributions

Pradipta Halder was primarily responsible for the study design, data analysis and writing the article. Javier Arevalo was responsible for conducting the survey and commenting on the article. Liisa Tahvanainen and Paavo Pelkonen also contributed by commenting on the article.

Conflicts of Interest

The authors declare no conflict of interest.

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