Micro-level sustainable biomass system development in Central Himalaya: Stress computation and biomass planning

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Abstract

Indian rural populations greatly depend on natural resources for meeting various biomass needs, especially in geographically difficult areas like Himalayas. A number of external interventions in the form of expansion of commercial fuels, afforestation, harvesting renewable energy sources, dissemination of fuel saving devices, etc. have been introduced to attain sustainability in meeting the energy demands. But major focus remains on inherent potential of the biomass system to produce various biomasses and meet fuel and fodder demands.

Present study analyzed biomass scenario in 25 villages in the Central Himalayas, identified issues in biomass planning, evolved methodologies for biomass estimation, computed end-use-wise stress and devised biomass management methodology. Possibilities of attaining sustainability in meeting fuelwood and fodder demands were reviewed based on the data from ten villages and the methodology has been detailed by taking a case of Nauli village. The methodology also suggests the ways by which a biomass planning may be integrated to non-biomass resources, technologies and schemes.

Introduction

Escalation of biotic pressure on natural resources has made the already fragile Himalayan ecosystem vulnerable to a variety of ecological maladies with flash floods, landslides, soil erosion and deterioration in soil productivity coming as a natural consequence. Stress on natural resources for fuelwood, ultimately leading to an energy crisis, is continuously rising because of increasing human as well as livestock population. Besides the persisting deterioration of effective tree cover, dwindling level of supply and increasing biomass demands, a loosing battle is being fought on the front of meeting fuel and fodder demands for subsistence. The energy, most vital stake of an ecosystem, consumption pattern in the region is firmly correlated to its natural resource base in area and invariably most of the energy demands are met by fuelwood, followed by dung, kerosene, electricity and then crop residues (Vasudevan and Santosh, 1987). The scenario calls for biomass planning, especially in the Himalayas, as almost 90 per cent of energy demand is met with biomass resources.

The need for decentralized management was felt long back. Micro-level planning provides opportunities to formulate regional and sub-regional policies and strategies on the basis of local details at several levels (Sundaram, 1980). A few natural resource management agencies have developed district level databases. Now the emphasis is being given to developing practical methodology to improve the quality of secondary information, filling gaps by collecting primary information and analyzing the available data to suit micro-level planning in developing sustainable biomass systems. The related methodological issues primarily involve defining resource-wise stress on various sources (cow dung, grass, shrub and trees) and use it as a guide to develop micro-level biomass plan.

The Study area

The characteristics of biomass system, issues involved and methodologies adopted, though have broad similarities, are area-specific. The paper is based on a study conducted in Irgad micro-watershed in Pauri Garhwal district of Uttar Pradesh (India) extending from 29^{o}51'53" to 30^{o}7'7" N latitude and 78^{o}44'58" to 78^{o}49'45" E longitude in Middle Himalayas with altitude ranging between 1100 to 2000 m.

The issues

Most researchers have recommended that rural energy planning is a subject of village development and should focus on the study of village (Vinod Kumar 1980). However, such planning requires identifying the boundary of the revenue unit and data is required at still smaller level (Vinod Kumar, 1987). More precise information on biomass system, biomass supply, consumption, landuse and site are required to be gathered. Using macro averages for productivity of crop-residue, cattle dung, grass and shrub often result in over estimation of supply, whereas not including the data on site quality, landuse, biomass system[2] may lead to an under estimation. For a micro-level study the data on landuse, vegetation and soils have to be at a level lower than a village instead of having one figure for cluster of villages or district.

[2]Biomass system includes the area/sources from which various biomasses are extracted.

Without identifying the areas and the resources being exploited by the villagers beyond village area, the biomass supply may be underestimated and the stress may appear unrealistically high. Hence, for district level planning it is crucial to define a biomass system for every village largely with the help of secondary data. Besides the usual problems of unavailability and false data, unsuitability and lack of periodic up-dating also pose serious problems in making correct estimations.

Besides accurate assessment of biomass supply and consumption, it is essential to know which of the resource from what type of landuse is being stressed for which end-use. A resource vis-à-vis end-use stress indicates the magnitude of pressure caused on a resource due to a particular end-use. The stress aid in estimating the strengths and weaknesses associated and determines the pre-requisites for an integrated plan. A micro-level biomass plan should perceive the impacts of the proposed strategies; identify various infrastructural requirements and assign specific role to various interacting agencies. The plan should ensure better interaction among various departments, reduce bias (except political) and provide a better scope for monitoring.

Methodologies adopted

To estimate the supply of biomass from various sources, like cattle-dung, crop residues, grasses, shrubs and trees, secondary information is needed and has to supplement by suitable primary data of the region. Some statistics from different sources as well as field estimates are presented in Table - 1. The data was used to compute biomass supply and consumption to assess local biomass scenario; but the procedure adopted in the stress computation and biomass planning are only discussed here.

Table 1. Methodologies for collecting data and norms calculated for the study area.

Information	Methodology used	Value	Units	Level
1. Cattle Dung				
a) Livestock	Primary survey	Variable		Family
b) Dung production	Primary survey	Variable	t	Village
c) Dung used for cakes	Primary survey	Variable	t	Village
d) Dry to wet weight ratio	Measurement	0.24		Micro-watershed
2. Agricultural crop residues				

a) Grain to straw ratio*	Measurement	Variable		Watershed
a) Irrigated rice		1:1.88		
b) Un-irrigated rice		1:1.83		
c) Jhangora		1:2.40		
d) Mandwa		1:2.10		
e) Wheat		1:1.99		
f) Barley		1:1.23		
b) Productivity of crops	Secondary data	Variable		District
a) Irrigated rice		1.059	t/ha	
b) Un-irrigated rice		1.059	t/ha	
c) Jhangora		1.091	t/ha	
d) Mandwa		0.932	t/ha	
e) Wheat		0.927	t/ha	
f) Barley		0.865	t/ha	
c) Area under various crops	Secondary data	Variable	ha	Village
d) Total area under a crop	Calculated	Variable	ha	Biosystem
e) Total agricultural land	Calculated	Variable	ha	Biosystem
3. Grasses				
a) Bheeta land ratio*	Measurement	0.23		Watershed
b) Village common land	Secondary data	Variable	ha	Village
c) Productivity*	Measurement	0.228	t/ha	Watershed
d) Share as per settlement	Calculated	Variable		Biosystem
e) Bheeta land	Measurement	Variable	ha	Biosystem
4. Shrub				
a) Productivity*	Measurement	7.092	t/ha	Watershed
b) Dry to wet ratio*	Measurement	0.47		Watershed
5. Trees				
a) Girth at Breast height	Primary survey	Variable	m	Tree
b) Height	Primary survey	Variable	m	Tree
c) Basal area	Primary survey	Variable		Canopy

d) Species	Primary survey			
e) Area under canopy	Secondary survey	Variable	ha	Village
a) Forest stock with in village		50	Year	
b) Forest stands		75	Year	
f) Form factor	Secondary data	Variable		Species
g) Volume	Calculated	Variable	cu m.	Canopy/village

t - Tonne, ha - Hectare, m - Metre
* Developed as local standards

Stress computation

Stress, the ratio between annual biomass consumption and sustainable supply, was computed for various end uses of different biomass resources. Cow dung is used as manure, fuel and plastering material. For computing the stress on cow dung production, the dung consumption for dung-cakes (fuel) and manure was clubbed and equated against total dung production. The recommended dose of 1 tonne Farm Yard Manure per hectare of agriculture land was taken as consumption level. The cow-dung being used for plastering, being very small was ignored. Grasses and crop-residues are fed to livestock and are consumed locally. Therefore, the stress on agricultural crop residue was always unity. The excess stress for fodder was met with from a supply of grass from outside the biomass system.

The sustainable yield from trees included the yield from scattered trees as well as forest canopies. Forest canopies could yield only fuelwood because timber extraction was not allowed without official permission. The stress caused due to timber requirement was computed only for the villages that had forest settlement and timber right. Quantity of timber sanctioned, as per the settlement was taken as the sustainable timber yield (from secondary sources). Total timber consumed in the village also includes the wood utilized for making doors, windows, supports, roofing material etc. As most of the wood is either replaced or at least equal amount is required for constructing new house in the period of 15 to 20 years, so 5 per cent of the total timber consumed in village was assumed as the annual consumption. The stress was computed by equating the sustainable yield against the timber consumed per year. To estimate the stress due to fuelwood, the annual shrub production and sustainable yield from trees is equated against the annual consumption of respective biomass for the end-use.

Biomass management plan

Various management strategies are suggested to minimize the stress in the target year for the biomass system to be self-sustainable. Besides the stress, information on site quality, sustainable yield contributed by fruit trees as well as miscellaneous species, supply of the species actually being consumed etc. may be used while framing the interventions. Efforts can also be made to estimate the scope of commercial and noncommercial energy sources, in case local sustainable biomass supply fail to meet the consumption in the target year.

Various strategies involved in planning are to:

- Conserve resources.
- Increase resources.
- Supplement the supplies through Public Distribution System (PDS) and/or RETs (Renewable Energy Technologies), if required.

The biomass plan should integrate resource conservation with the overall development of the village. An improvement in agriculture increases crop-residue production that may replace tree biomass from being used as fodder and encourage timber or fuelwood yield. Moreover, it may enhance the purchasing power and hence provide room for fuel-efficient devices, based on conventional and non-conventional energy sources.

Interventions

The recommended intervention would depend upon the degree of stress. Various techniques of biomass conservation, protection and production needs to be employed under different biomass scenarios. In extremely stressed conditions, interventions with a combination of biomass conservation, protection and production may be required or else means to increase supply from external sources may be sought. For example to meet fuel needs, an increase in quota of commercial fuels or an introduction of renewable energy technologies may be sought (Table 2).

Table 2. Resource-wise stresses and interventions

S.No.	Stress	Guideline	Interventions
1.	Below 0.8	Try maintain sustainability	• No interventions required. • Plan for checks on population, consumption pattern. • May include conservation strategies.
2.	0.8-1.3	Conservation	• Control over population and livestock.

			• Reduction of grazing stock. • Introduction of improved *chulhas*, biogas, solar thermals etc.
3.	1.3-1.65	Protection and conservation	• Resolve disputes over common-property, ensure equal distribution. • Rational grazing, cyclic harvest, harvest as well as stall feeding and other techniques of pasture land management. • Increase biomass development schemes and tap alternate energy sources. • Introduce fuel saving devices. • Increase stall-fed days. Etc.
4.	1.65-1.9	Production	• Grass, shrub, tree plantation (with soil working). • Introduce improved varieties and practices (including agriculture). • Review and improve land-use pattern. Etc.
5.	1.9-2.3	Conservation, protection and production	Above all
6.	Above 2.3	Introduction of external sources and raising the purchasing power	• Increase local quota of commercial fuels. • Encourage local income generating activities. • Introduction of renewable energy technologies. Etc.

The conceived interventions call for various tangible and non-tangible inputs as pre-requisites. The inputs can be a village co-operative to ensure people's participation, financial institutions to encourage village-based income generating activities, marketing federations to provide different inputs and sell various outputs, extension as well as technical support from government and non-government organizations, etc. Implementation of any of the programs without the pre-requisites may produce a disproportionate impact. Like, a partial implementation of interventions or adoption of a program by only a fraction of the target group will generate an impact. But it is possible that the impact may not make a check the existing biomass crisis. However, a lower stress from 1.2 to 1.4 may be mitigated through the strategies. For a higher stress, mass movement and massive participation becomes inevitable.

Biomass management plan for village Nauli: A case study

Village Nauli has 228 animals and 293 human beings but can sustain only 89 animals and 174 human beings at the present level of biomass supply and consumption. Future projection of the demand is based on the expected population growth as per the trends of population growth in the village over last two decades. The stress on different biomass resources reflects a fodder and fuel crisis (Table 3).

Table 3. Biomass demands (tonne) and stress in village Nauli

Year	Cattledung		Crop residue	Grass	Shrub	Scattered tree
	Dung-cakes	Manure				
1992						
Production	36.0	52.0	60.0	87.0	63.0	9.0
Demand	36.0	43.0	60.0	315.0	109.0	12.0
Stress	1.00	0.83	1.00	3.62	1.73	1.34
2002						
Demand	39.8	43.0	60.0	354.9	120.6	13.3
Stress	1.00	0.89	1.00	4.08	1.91	1.48
2012						
Demand	44.1	43.0	60.0	399.9	133.5	14.7
Stress	1.00	0.98	1.00	4.60	2.12	1.64

Moderately high stress was observed in the village and relevant interventions are framed in accordance with the stress on various biomass resources (Table 4). Conservation strategies were in-applicable and hence, the suggested interventions start from biomass generation.

Table 4. Resource-wise stress and imperatives

Resource	Stress	Imperatives
Cow-dung (Manure)	0.83	- Try maintain sustainability
Crop residue	1.00	- Conservation

Grass	3.62	- Protection, conservation and production - Introduction of external sources and raising the purchasing power.
Shrub	1.73	- Production
Scattered trees	1.34	- Conservation and protection

Biomass generation

Organic manure: Since there is no problem with organic manure no intervention is required. Keeping in view a possibility of diverting cattle dung for meeting fuel needs,

- Introduce composting technologies to improve cow-dung use efficiency.
- Manage fuel crisis with alternatives like biogas, to check dung-cake demand and maintain manure supply.

Fodder: The stress is reflected on grasses only but interventions are employed over both, the crop residues as well as grasses. The stress is too enormous to be met by local resources no matter whatsoever is the level of production and management. Radical initiatives are required on the part of villagers as well as implementing agencies.

- Reduce livestock. And to start remove grazing stock.
- Review landuse and allocate maximum possible land to pasture development.
- Introduce improved grasses, fodder crops and better varieties suitable under rainfed agriculture.
- Various techniques of pasture land management (closure, rotational grazing, cut and feed, grass as well as shrub planting etc.) may be tried.
- *Chir, Banj, Reetha* and *Babul* plantations as well as grass and shrub plantations on suitable sites (Site and species were identified after site quality assessment).
- Fodder depots may be installed.
- Dairy may be encouraged (role of a marketing agency is crucial) to regulate livestock, enhance purchasing power of villagers and mitigate fodder crisis.

Fuel: The stress on trees may be weaned away by adopting conservation and protection measures. Also the shrub production can be increased.

- Protection to common land and resources.
- Cyclic harvest from common lands.
- Shrub plantations with some soil working.

- Adoption of solar thermals, improved *chullha* and biogas (six plants possible, considering the livestock and water availability).
- Beating-up plantations in village forest.

Biomass management

Crop residues and grasses may increase to 1.4 and 2.0 times, respectively. But to mitigate the stress due to fodder, either livestock is to be reduced or external sources have to be employed. It requires people's participation.

The six biogas plants installed may save 10 tonne of wood and also maintain the supply of organic manure. A shrub plantation on 20 ha of common land (with closure) after five years shall be able to sustain annual shrub fuel demand till 2012 AD. The supply will rise to 1.6 times. The villagers should decide the mode of reducing livestock, sharing pair of bullocks and also type of the closure (fencing, watchman, social fencing etc.).

Micro-level sustainability

Twenty-five villages were studied but the results of only ten selected villages are presented.

Table 5. Micro-level sustainability

Village	Presently sustainable	Sustainability achievable	Stress due to				Risk (if any)
			Manure	Fodder (grasses)	Fuel (Shrubs)	Fuel (trees)	
Agrora	No	Yes	1.5	1.4	0.77	0.52	
Thapli	No	Yes	1.15	1.7	1.98	0.64	Fuel
Ghiri	No	No	1.00	2.14	1.77	2.03	
Kadola	No	Yes	0.69	1.32	1.43	1.83	Fuel
Jaspur	No	Yes	0.61	2.26	1.05	1.25	Fodder
Noselu	Yes	Yes	0.94	0.54	1.00	0.19	
Teuthiya	No	Yes	0.79	1.2	1.89	0.61	Fuel
Andriyo	No	Yes	0.60	0.80	0.47	0.13	Fodde

n							r
Toli	No	No	0.58	2.06	1.51	2.06	
Nauli	No	Yes	0.83	3.62	1.73	1.34	Fodde r

Presently only one village is able to satisfy biomass demands from local resources and by resource management eight villages shall become sustainable in biomass. However, there will be a risk to meet fuel or fodder demand in three villages (Table-5). The element of risk arises incase of lack of anticipated people's participation, required mass movement and adoption. Two villages i.e. Ghiri and Toli shall not be able to meet local biomass needs without some external interventions like biogas plants, solar thermals, increase in quota of Kerosene oil or plantation of suitable vegetation to grow required biomass and to modify even livelihoods (if needed).

Spatial planning

Interventions are designed according to the stress and gets linked with different schemes on development of various biomass resources, land reclamation (change of landuse, soil conservation, etc.), utilization of natural resources (rain-water harvesting, hydel power, renewable energy technologies, etc.) and employment generation (agriculture, horticulture, agro-forestry, apiculture, sericulture, dairy, etc.). District authorities may identify village-wise biomass scenario and assess the stress, largely by using the secondary data already available with the authorities. The planners should generate spatial information about the distribution of various biomass-stressed villages. The information may be used for assigning suitable development schemes to the needy villages. Also, priority areas may be identified for implementation and adoption rate may also be roughly worked out.

Table 6. Stress on resources and linkages

Stress on	Uses	Linked schemes
Cattledung	Manure	Improving agriculture, Biogas & composting promotion
Crop residues	Fodder & Fuel	Introduction of better crop varieties and agriculture implements
Grasses	Fodder	Soil conservation, Biomass (grasses) development schemes, alteration in cropping & landuse pattern
Shrubs	Fuel	Restoration of succession and shrub production (plantations), efficient cookstoves, introduction of commercial fuels by

		efficient PDS, Renewable energy technologies (Biogas, Solar thermals etc.)
Scattered trees	Fuel	Conserve biodiversity (disappearing species), encouraging commercial fuels & purchasing power of villagers
Canopy	Fuel	Manage village forests, reduction & management of the demand
Canopy	Timber	Changes in livelihood and standard of living (Employment generation)

For instance, the schemes on renewable energy technologies (Photo Voltaic, Biogas, Solar thermals, improved cook stoves etc) and expansion of commercial energy network (kerosene depot, LPG agency etc.) may focus, on priority, the areas heavily pressing the natural biomass sources for energy purposes. Similarly sites as well as species may be identified for plantations. Moreover, the generated information helps in identifying the role of different implementing agencies, as specific jobs to be carried out as well as their sequence in a village may be determined. Thus providing chance for better monitoring.

Conclusion

Developing micro-level sustainable biomass systems is not possible in all the villages. Most of the villages may regain sustainability in meeting their biomass demands, provided interventions based on external aid are induced. External aided interventions include special fodder development schemes, improved pasture land management systems, fuelwood plantations, biogas scheme, introduction of new agricultural varieties or crops, increased commercial fuel supply, etc. A few villages may not need the aided interventions but in others, labour intensive and highly demanding interventions have to be employed at the earliest. Among the villages, a few villages may face a threat of un-sustainability in one or more aspects even after adopting a well-focused management for a long time. The villages and the ones, which may not attain sustainability at all, should also be identified while preparing district level development plans. Reviewing the village-level biomass scenarios, suitable natural resource conservation as well as development schemes may be identified, allocated and implemented.

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