Research Journal of Environmental Sciences

ISSN 1819-3412

Academic
Journals Inc.

www.academicjournals.com

Research Journal of Environmental Sciences 2 (3): 170-184, 2008
ISSN 1819-3412

Geographical Information System Approach for Regional Biogas Potential Assessment

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Abstract: The economic prosperity and quality of life in a region are closely linked to the level of its per capita energy consumption. In India more than 70% of the total population inhabits rural areas and 85-90% of energy requirement is being met by bioresources. With dwindling resources, attention of planners is diverted to viable energy alternatives to meet the rural energy demand. Biogas as fuel is one such alternative, which can be obtained by anaerobic digestion of animal residues and domestic and farm wastes, abundantly available in the countryside. Study presents the techniques to assess biogas potential spatially using GIS in Kolar district, Karnataka State, India. This would help decision makers in selecting villages for implementing biogas programmes based on resource availability. Analyses reveal that the domestic energy requirement of more than 60% population can be met by biogas option. This is based on the estimation of the per capita requirement of gas for domestic purposes and availability of livestock residues.

Key words: Energy, bioresource, agro ecosystems, biogas, animal waste, resource potential, GIS

INTRODUCTION

Energy plays a crucial role in diverse processes and activities that take place in the society. Energy is a complex process as it is possible to convert it into different forms, transport it, store it in some forms and use it in various end use modes in numerous places. Most of the energy sources are substitutable to each other due to the fact that some form of energy can be converted to other form (Ramachandra, 2003). The burgeoning population coupled with developmental activities based on ad-hoc decisions has led to resource scarcity in many parts of India. Energy demand is increasing and its inability to step up production to meet demand, has increased India's reliance on costly imports, the gap between consumption and production projected to widen into the next century, as demand for energy is projected to grow at an annual rate of 4.6%- one of the highest in the world (Ramachandra *et al.*, 2006). Present fossil fuel potential is unable to meet the growing demands of the society. In an attempt to stem the projected deficit between production and consumption, particularly for the increasing residential sector, which accounts for approximately 10% of total energy use and provide for an expanding rural sector, the government is pursuing alternative measures of energy provision. Post oil crises shifted the focus of energy planners towards renewable resources and energy conservation. Biomass is one such renewable, which accounts for nearly 33% of a developing country's energy needs. In India, it meets about 75% of the rural energy needs. In Karnataka, non-commercial energy sources like firewood, agricultural residues, charcoal and cow dung account for 53.2%. Renewable energy potential is high on the subcontinent and rational decision-making at disaggregated levels is necessary to eliminate wasteful use of resources (Ramachandra and Shruthi, 2007).

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Detailed planning would be required from National, to State, to District, to Taluk and Village levels. The inappropriate selection and site matching of species or management strategies can have adverse effects and lead to the degradation and abandonment of land. However, the correct selection of plant species can allow the economic production of energy crops in areas previously capable of only low plant productivities. Simultaneously multiple benefits may accrue to the environment. Such selection strategies allow synergistic increases in food crop yield and decreased fertiliser applications while providing a local source of energy and employment.

Rural population of India still depends on the traditional devices for cooking and water heating, space heating, which is energy inefficient, leading to excess consumption of local resources. Lack of information about the resources and technologies may be cited as the reason for this situation. This necessitates the understanding of the present energy consumption pattern and exploring locally available alternative energy sources in order to ensure resource sustainability. Cattle dung is predominantly being used in rural area either for preparing farmyard manure by composting it or directly preparing dung cakes for burning as cooking fuels. Preparation of cakes and burning are highly uneconomical and unhygienic. In this context, anaerobic digestion of animal residues not only provides valuable cooking fuel, in the form of biogas and enhances the manure value of the waste but also provides a convenient, safe and aesthetic waste disposal method.

In this study, the biogas resource base in Kolar District in Karnataka State, India is analysed villagewise and talukwise. This entails spatial analysis of resources, necessitating the usage of spatial technologies such as GIS. This would help the planners at disaggregated level (villages) to implement development programmes to meet the daily requirement of energy. This analysis is replicable to any region across the globe. Geographical Information System (GIS) is an information system that is designed to work with data referenced by spatial or geographic coordinates used to map spatially the resources and demand. It helps to efficiently store, manipulate, analyse and display spatial data according to the user specifications. Maps provided by GIS reveal the spatial patterns that cannot be captured by conventional methods such as tables and histograms. GIS integrates common database operations, such as query and statistical analysis, with the spatial data (maps). These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for planning strategies and managing infrastructure in a region.

Energy and biogas potential of livestock residues of all major groups of stock-raising animals (cattle, buffalo, sheep, goat) can be evaluated using GIS. GIS based database management system is superior over conventional methods for estimation of biogas potential from livestock residues as temporal information (such as number and type of livestock, dung yield) can be incorporated into spatial databases. GIS provides the area of the region of interest, which can be used for calculating livestock density and dung yield and hence the biogas potential can be estimated. The GIS layer containing such information is useful to identify regions of extensive availability of dung for biogas generation. Biogas from plant and animal wastes is a viable energy alternative to meet the growing demand in rural areas for domestic and agricultural activities. Biogas technology has made inroads in rural economy in many districts (such as Uttara Kannada, Udupi, Shimoga) in Karnataka state during the last two decades due to economic viability, ecological soundness, technical feasibility and social acceptance.

Biogas is produced by biological decomposition of organic material in the absence of air. The conversion of animal waste and agricultural residues to biogas through anaerobic digestion processes can provide added value to farm livestock manure as an energy resource. Since the 90's, India has supported projects involving studies related to the generation of renewable energy. To that effect, a series of strategies and political initiatives have been built to support research and for the generation and utilization of this type of energy, which have favored programs of sustainable development in the country. In this context, the biogas technology (anaerobic digestion) has gained importance (Chanakya ***et al***., 2007).

The potential of biogas from agricultural residues and dung from India's 300 million cattle is approximately estimated at 17,000 MW. Biogas technology is a particularly useful system in the agro-ecosystems and can fulfill several end uses. The gas is useful as a fuel substitute for firewood, agricultural residues, electricity, etc. depending on the nature of the task and local supply conditions and constraints, thus supplying energy for cooking and lighting. Biogas systems also provide a residue organic waste, after anaerobic digestion that has superior nutrient qualities over the usual organic fertilizer, cattle dung, as it is in the form of ammonia. Small-scale industries are also made possible, from the sale of surplus gas to the provision of power for rural-based industries, which may also provide the user with income generating opportunities. The gas can also be used to power engines, in a dual fuel mix with diesel (http://mnes.nic.in/ach1.htm) and can aid in pumped irrigation systems.

Apart from the direct benefits gleaned from biogas systems, there are other, perhaps less tangible benefits associated with this renewable technology. By providing an alternative source of fuel, biogas can replace the traditional biomass based fuels, notably wood. Introduced on a significant scale, biogas may reduce the dependence on wood from forests and create a vacuum in the market, at least for firewood. With 70% population still in rural areas, there is tremendous demand on resources such as fuelwood, agricultural residues, dung cake, etc. to meet the fuel requirements for cooking, water heating and space heating (during winter). Dependence on bioresource to meet the daily requirement of fuel, fodder in rural areas is more than 85% in many rural districts in India (Ramachandra *et al*., 2004).

India is a pioneer in the field of developing technology for biogas production from animal residues (dung) since mid 90's. About 70,440 plants have been completed during the period April to December 2002, which is almost 117 per cent over the target of 60,000 plants planned for the corresponding period (MNES Annual Report, 2003). Animal dung is a potentially large biomass resource and dried dung has the same energy content as wood. When burned for heat, the efficiency is only about 10%. About 150Mt (dry) of cow dung are used for fuel each year across the globe, 40% of which is in India. But dung is readily recoverable only from confined livestock or in settings where the labour costs associated with gathering dung are modest. The efficiency of conversion of animal residues could be raised to 60% by digesting anaerobically (to produce biogas). Biogas production will also resolve the conflict between energy recovery and nutrient utilisation as the effluent from the digester could be returned to the fields.

Biogas has a higher heating value than producer gas and coal gas, which implies increased services. As a cooking fuel, it is economical and extremely convenient. Based on the effective heat produced, a 2 m^3 biogas plant could replace, in a month, fuel equivalent of 26 kg of LPG (nearly two standard cylinders), or 37 litres of kerosene, or 88 kg of charcoal, or 210 kg of fuelwood, or 740 kg of animal dung. Also biogas has no danger of health hazards, offensive odour and burns with clean bluish soot less flame thereby making it non-messy to cooking utensils and kitchens. In terms of cost, biogas is more economical, on a life cycle basis, than conventional biomass fuels (dung cakes, fuelwood, crop wastes) as well as LPG and is only fractionally more expensive than kerosene; the commercial fuels like kerosene and LPG, however, have severe supply constraints in the rural areas (Soma *et al*., 1997). Biogas technology enhances energy supply decentralization, thus enabling rural areas meet their energy requirements especially when the commercial fuels are inaccessible for their use. A comparison of directly using the dung and its use as biogas shows a 25 kg fresh dung would give about 5 kg of dry dung, which is equivalent to one m^3 of biogas. Comparative analysis of direct burning and biogas considering various parameters are listed in Table 1.

Table 1: Comparison of direct burning of dung and its use as biogas

Parameters	Direct burning	Biogas
Gross energy	10460 kcal	4713 kcal
Device efficiency	10%	55%
Useful energy	1046 kcal	2592 kcal
Manure	None	10 kg of air dried

(Source: http://www.teriin.orgh/renew/tech/biogas)

Biogas is basically methane (CH_4) produced through the anaerobic fermentation of dung and other organic wastes. Besides methane, biogas also contains carbon dioxide and traces of nitrogen, sulphur and moisture. Biogas production is primarily a microbial process wherein the carbohydrates in the organic matter break down in the absence of oxygen. The methane content in the gas produced depends on the feedstock. The gas production is also influenced by temperature, acidity, solid content and C/N ratio. A temperature of 35°C-40°C, pH range 6.6-7.5, solid content of 7-9% and C/N ratio of 25:1-30:1 are considered optimum (Chanakya *et al*., 2007). Animal residue has a solid concentration of 20% and therefore to attain the desired value of 7-9%, it is mixed with water (1:1). It also has a C/N ratio of 25:1(the ratio varies for different raw materials) and thus is an ideal choice as it meets most of the requisites for optimum gas production. A kilogram of dung produces 40 L of biogas and a family size biogas plant (2-4 m^3) requires 50 kg of dung and equal amounts of water to produce 2000 L of gas/day, which would be sufficient for cooking purposes in a family of 4-5. The calorific value of biogas is obtained by multiplying that of methane with the volume fraction of methane in biogas. The calorific value of methane is 8548 Kcal m^{-3} (Ravindranath and Hall, 1995; http://www.teriin.org/).

For several decades, biogas has been promoted as an appropriate rural technology, enabling an effective utilization of a local resource. It is a clean and convenient fuel at low cost, besides being environmentally friendly. Women no longer have to spend hours away from their homes, traveling (often long) distances to collect wood for cooking and heating, they can free up valuable time for activities, which they would otherwise be unable to do. A smoke-free and ash-free kitchen means women are no longer prone to lung and throat infections and can look forward to a longer life expectancy. It is suitable for practically all the fuel requirements in the household, agriculture and industrial sectors. For instance, domestically, it can be used for cooking, lighting, water heating, running refrigerator, water pumps and generators. Agriculturally, it can be used on farms for drying crops, pumping water for irrigation and other purposes. An important benefit of the technology is saving on fuel wood. Construction of biogas plants also creates good employment opportunities in rural areas. The use of biogas plant produces fuel as well as fertilizer, while only one of these is possible if dung is used as it is. The greatest advantage of biogas plants is that they can digest almost any constant (wet) mixture of city waste, manure and plant residues due to complex bacterial process involved. It dose not reduce the ammonia nitrogen content from livestock manure during anaerobic process and kills all the pathogens and weed seeds.

While the overall impacts of the biogas programme have been appreciable, there are several aspects, which need to be strengthened and streamlined further to enhance effectiveness. There are several technical, economical and institutional barriers, which hinder the dissemination of biogas development in India (Soma *et al*., 1997). Most of these barriers are interlinked and often have a cause-and-effect relationship with each other. The barriers in biogas dissemination programme could be categorized as:

- Technical (Lack of quality control in raw materials and accessory, water scarcity in dry arid region and lack of trained manpower)
- Institutional (Ineffective repair and maintenance strategy, poor service backup to handle the technical hiccups in field during the operation and delay in the payments)
- Economical (Escalating installation and operation costs, inadequate government support (like loans, subsidies) and government programs not reaching the needy)

Nigeria produces about 227,500 tons of fresh animal wastes daily (Akinbami *et al*., 2001). The projected quantity of family-sized biogas digesters into the future ranges between 144,350 and 2,165,250 units. This is based on the assumption that 1 kg of fresh animal wastes produces about 0.03 m^3 gas and a 6.0 m^3 family-sized biogas digester will generate 2.7 m^3 of biogas per day to satisfy the cooking requirement of a household of an average size of 9 persons..

Total energy generation potential from the anaerobic digestion of industrial wastewater in India is estimated to be 2963 GWh_e/a equivalent electric energy by Kusum *et al.* (2002). The study indicates a potential of 565 MW plant installations with anaerobic digestion technology. The pulp and paper industry has the maximum potential among others of the order of 1131 GWh_e/a followed by distillery with a contribution of 830 GWh_e/a to a total potential of 2963 GWh_e/a equivalent electric energy.

Purohit *et al.* (2002) explored the renewable energy option for domestic cooking in India. The estimate shows 38 million family size biogas plants in the optimistic scenario and 29 million in the realistic scenario based on 1991 statistics on the bovine population and ownership pattern. In the optimistic scenario a total of about 65 million m^3 of biogas can be produced daily using bovine dung at the household level with about 38 million (about 18.5 million of 1 m^3, 12.1 million of 2 m^3 and 7.4 million of 3 m^3 capacity biogas plants). The realistic scenario estimates are 19.3 million 1 m^3 biogas plants, 6 million 2 m^3 biogas plants and 4 million 3 m^3 biogas plants totaling to about 29.3 million biogas plants capable of producing about 43.4 million m^3 biogas everyday. In both the scenarios the potential number of 1 m^3 biogas plants is far larger than the combined potential 2 and 3 m^3 biogas plants. With a properly maintained 1 m^3 biogas plant it may be possible to meet a major fraction of the domestic cooking requirement of a family of three to four adult members during most of the year.

Village level domestic energy consumption pattern across coastal, interior, hilly and plain zones considering regional and seasonal variation for Uttara Kannada District, Karnataka, India show that biogas for cooking ranges from 0.276 to 0.775 m^3/person/day. 1304 households were surveyed among which only 18 households used biogas for cooking where, 2 households were from low income category, 9 from middle and 7 from high income category. Biogas consumption ranges from 0.200 (low income) to 0.596 (high income) m^3/person/day. Households using biogas for cooking also uses kerosene to supplement their cooking fuel requirements (Ramachandra *et al*., 2000a).

Energy and biogas potential of livestock residues of all major groups of stock-raising animals were evaluated using ABEPE (Animal (data)Base for Energy Potential Estimation), a GIS based biomass resource assessment application using a relational database management system. The estimated biogas production and energy potential as forecasted through ABEPE for the year 2010 is 423.6 million m^3 and 9148 TJ respectively (Batzias *et al*., 2005).

Ecologically sound development of the region is possible when energy needs are integrated with environmental concerns at local and global levels, for which an integrated planning framework would be necessary. A GIS based decision support system would provide the planner a receptive and efficient tool to analyse and visualize spatial and temporal data. This would help in formulation of an integrated planning framework necessary for the ecologically sound development. Currently, energy planning in India is not an integrated activity. Since there are many energy sources and end uses, many organisations and agencies deal with different aspects of energy. The current approach to planning in the energy sector does not offer any significant role to the district or local level institutions. Moreover, the coordination needed between the energy sector and the overall planning and development at district (Federal State is divided into districts for administrative purposes), taluk (a district is divided into taluks) and village (a taluk is divided into villages) levels is missing. Although the forest department carries out forestry planning, its most significant aspect pertaining to energy is extremely weak and receives very little attention in the planning exercises of the sector. The biomass situation in hilly taluks has, therefore, gradually worsened and has reached a point of crisis (Ramachandra, 2003). This deteriorating situation obviously demands immediate attention in two directions.

- Strengthening of local institutions for energy development. Local government institution at the block level (cluster of villages) and below can contribute positively in many ways towards energy planning and development. These include generation of energy databases, promotion of community participation, extension and training.

- Promotion of coordination between institutions concerned with the energy development and overall planning at different hierarchical levels on the one hand and between institutions concerned with research and development on the other.

MATERIALS AND METHODS

Study Area

Kolar District is located in the southern plains of Karnataka State, India. It lies between 77°21' to $78^0$35' east longitude and 12°46' to 13°58' north latitude and extends over an area of 8,225 km^2. The population was 25.23 lakh in 2001. For administrative purposes the District has been divided into 11 Taluks. There are 3,345 inhabited villages in the district. Kolar belongs to the semi arid zone of Karnataka. Study area is shown in Fig. 1. In the semi arid zone apart from the year-to-year fluctuations in the total seasonal rainfall, there are also large variations in the time of commencement of rainfall adequate for sowing as well as in the distribution of drought periods within the crop-growing season. Kolar district depends on the rainfall during southwest and northeast monsoon. Out of about 280,000 hectares of land under cultivation, 35% is under well and tank irrigations. There are about 951 big tanks and 2934 small tanks in the district.

The average population density of the district is 2.09 persons ha^{-1} (rural) and 2.69 persons ha^{-1} (rural + urban). The population density ranges from 1.44 (Bagepalli), 1.69 (Gudibanda), 1.70 (Srinivasapur) to the maximum of 2.55 (Kolar). While, the population density in taluks lies within this range-Bangarpet (2.52), Malur (2.38), Gauribidanur (2.36), Sidlaghatta (2.16), Chintamani (2.10), Mulbagal (2.04), Chikballapur (1.92).

The total forest area of Kolar district is 1039.41 km^2 i.e., 12.64 % of the total geographical area. It ranges from 1.71% (Bangarpet), 2.3% (Malur), 2.78% (Kolar) to 15% (Srinivasapur) and 20% (Chikballapur). Taluks are grouped into three (<10%, 10-20% and >20% cover) based on percentage of forest cover. Chikballapur and Bagepalli have forest cover > 20%, Gudibanda and Srinivasapur are in the range of 10-20% while remaining taluks have forest cover < 10%.

Methods

Data Collection

Livestock is an important component of an agro ecosystem. For instance, livestock provide the critical energy input to the croplands required for ploughing, threshing and other farm operations. Animal dung provides essential nutrients required for soil fertility and crop yields in the form of organic manure. Livestock data was compiled from State Veterinary Department, Government of Karnataka and population density of cattle, buffalo, goat and sheep are found village wise. Data such as livestock (Cattle and Buffalo) population, animal residue and energy demand for domestic purpose data were considered for evaluating biogas potential in a village. Livestock density is evaluated village wise as follows.

$$\text{Livestock density} = \text{Livestock population}/\text{Area of the region}$$

Based on this parameter, thematic maps were generated for each taluk, which gives an idea about the livestock in different villages and also helps in comparative analyses.

Biogas Potential

Biogas is a product of anaerobic fermentation of organic matters and consists of around 60-70% Methane, 30-40% Carbon dioxide. The input material for the biogas materials for biogas digesters are the wastes that are found locally such as animal dung, agricultural residues and leaf litters from forests. The residues are introduced into a closed digester, where without the presence of free oxygen, the

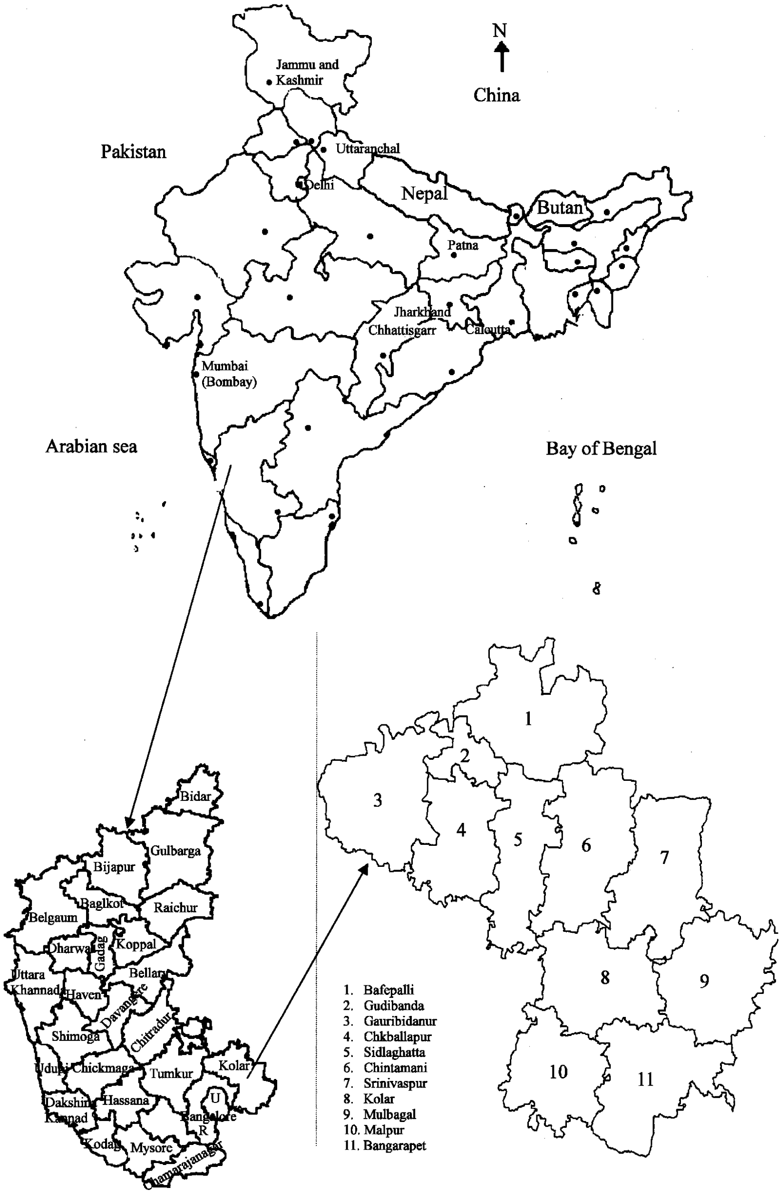

Fig. 1: Study area

responsible microorganisms work successively to convert complex organic matter into CH_4, CO_2, H_2, H_2S (Ramachandra, 2003). Quantity of dung yield per cattle varies from place to place. Survey carried out in 1500 households spread across all taulks in the district during January 2005-July 2006 shows that dung available per animal in case of cattle is about 3-7.5 kg/adult animal, buffaloes 12-15 kg, stall fed buffalo about 15-18 kg and hybrid variety is about 15-18 kg. By considering the lower figures (such as 3 kg/cattle/day and 12 kg/buffalo/day), total dung available per day per village is evaluated. With the assumption of 0.036 m^3 of biogas yield per kg of cattle/buffaloes dung, the total quantity of gas available (if all is used for biogas) is estimated. It gives the amount of biogas available per village (in low case) (Ramachandra *et al*., 2005).

Similarly on considering the high figures i.e., (7.5 kg cattle^{-1} day^{-1} and 15 kg buffalo^{-1} day^{-1}), total biogas is estimated per day per village and with assumption of 0.042 m^3 of biogas yield per kg of cattle/buffaloes dung. It is estimated that per capita requirement of gas for domestic purposes is about 0.34-0.43 m^3 day^{-1}. Biogas demand is computed by multiplying the adult equivalent of a village population and per capita biogas requirement. Demand of 0.34-0.43 m^3 day^{-1} was considered for computing low and high values of biogas demand in a village (Ramachandra *et al*., 2004). Ratio of biogas availability to the demand provides us an idea of the resource status in a region or it gives an idea of the proportion of population's domestic energy requirement could be met by biogas option. Four scenarios were computed depending on resource availability (low and high) and demand (low and high).

Case 1: Resource (Low)/Demand (Low)

This is computed, taking dung yield as 3 kg animal^{-1} day^{-1} for cattle, 12 kg animal^{-1} day^{-1} for buffalo and lower value per capita biogas requirement for domestic activities (0.34 m^3 day^{-1}).

Case 2: Resource (Low)/Demand (High)

This is computed, taking dung yield as 3 kg animal^{-1} day^{-1} for cattle, 12 kg animal^{-1} day^{-1} for buffalo and higher value per capita biogas requirement for domestic activities (0.43 m^3 day^{-1}).

Case 3: Resource (High)/Demand (Low)

Taking dung yield for cattle as 7.5 kg animal^{-1} day^{-1}, for buffalo as 15 kg animal^{-1} day^{-1}, per capita requirement of biogas (low value) i.e., 0.34 m^3 day^{-1}, biogas potential for resource (high) to demand (low) was calculated for all villages in the district.

Case 4: Resource (High)/Demand (High)

This is based on higher values of dung yield for cattle (7.5 kg animal^{-1} day^{-1}) and buffalo (15 kg animal^{-1} day^{-1}) and higher value of per capita requirement of biogas (i.e., 0.43 m^3 day^{-1}).

Districts map with taluk boundaries and taluk map with village boundaries was digitized to generate base layers using GIS package MapInfo Professional 6.0 considering Survey of India toposheets (1:50000 scale) and the cadastral map (1:6000 scale) of Kolar. Mapinfo can extract data from an RDBMS (Relational Database Management System). Many thematic maps can be created on the distribution of biogas or bioenergy for a specific year or its predicted values for the future In addition, villagewise livestock density, biogas availability and its demand, biogas status in a village can be illustrated.

The attribute data added to the base layer includes livestock density, area of the village, dung yield and biogas potential. Based on these computations taluk wise biogas availability maps were generated using GIS. The talukwise potential is evaluated using maps of administrative boundaries (taluk boundaries) and statistical data. The theoretical potential is presented as a thematic map of the total amount of biogas available in each region considering various scenarios. The information contained in such a map helps to identify regions' biogas status that would help in dissemination and implementation of energy programmes.

RESULTS AND DISCUSSION

Biogas from animal wastes is an alternative viable rural energy, provided sufficient feedstock is available. The biomass (animal waste) availability in Kolar district is analysed using a spatial and temporal tools such as GIS. This uses a spreadsheet as biomass resource management tool, incorporating 'MapInfo' as a GIS. Energy and biogas potential of livestock residues of all major groups

Table 2: Taluk wise livestock density

Taluks	Villages	0-2	2-4	4-6	6-8	8-10	>10
Bagepalli	229	212	15	1	1		
Bangarpet	391	347	35	7	1		1
Chikballapur	254	213	28	9	2	2	
Chintamani	410	375	32	1		2	
Gauribidanur	238	218	15	3	1		1
Gudibanda	108	61	33	9	4		1
Kolar	363	352	10	1			
Malur	366	299	43	15	7	2	
Mulbagal	346	329	14	1	1	1	
Sidlaghatta	291	240	24	17	5	2	3
Srinivasapur	349	314	26	5	2	1	1

Table 3: Taluk wise biogas potential

Taluks	0-20%	20-40%	40-60%	>60%
Case 1: Resource (low)/Demand (low)				
Bagepalli	87	108	21	13
Bangarpet	252	99	13	27
Chikballapur	128	65	25	36
Chintamani	165	160	56	29
Gauribidanur	90	101	31	16
Gudibanda	24	8	60	16
Kolar	167	135	43	18
Malur	239	62	22	43
Mulbagal	204	107	20	15
Sidlaghatta	139	65	31	56
Srinivasapur	161	115	41	32
Case 2: Resource (low)/Demand (high)				
Bagepalli	135	71	14	9
Bangarpet	301	60	10	20
Chikballapur	142	68	13	31
Chintamani	198	166	34	12
Gauribidanur	124	89	16	9
Gudibanda	24	49	25	10
Kolar	208	125	20	10
Malur	263	54	14	35
Mulbagal	249	74	12	11
Sidlaghatta	159	64	20	48
Srinivasapur	195	110	21	23
Case 3: Resource (high)/Demand (low)				
Bagepalli	32	43	78	76
Bangarpet	122	114	88	67
Chikballapur	88	41	41	84
Chintamani	110	64	102	134
Gauribidanur	52	56	65	65
Gudibanda	24	0	0	84
Kolar	97	114	77	75
Malur	192	57	38	79
Mulbagal	136	63	90	57
Sidlaghatta	107	37	45	102
Srinivasapur	102	60	72	115
Case 4: Resource (high)/Demand (high)				
Bagepalli	34	93	65	37
Bangarpet	146	148	59	38
Chikballapur	101	47	46	60
Chintamani	121	103	115	71
Gauribidanur	62	84	54	38
Gudibanda	24	0	0	84
Kolar	119	133	76	35
Malur	210	59	32	65
Mulbagal	145	112	56	33
Sidlaghatta	116	55	43	77
Srinivasapur	111	89	84	65

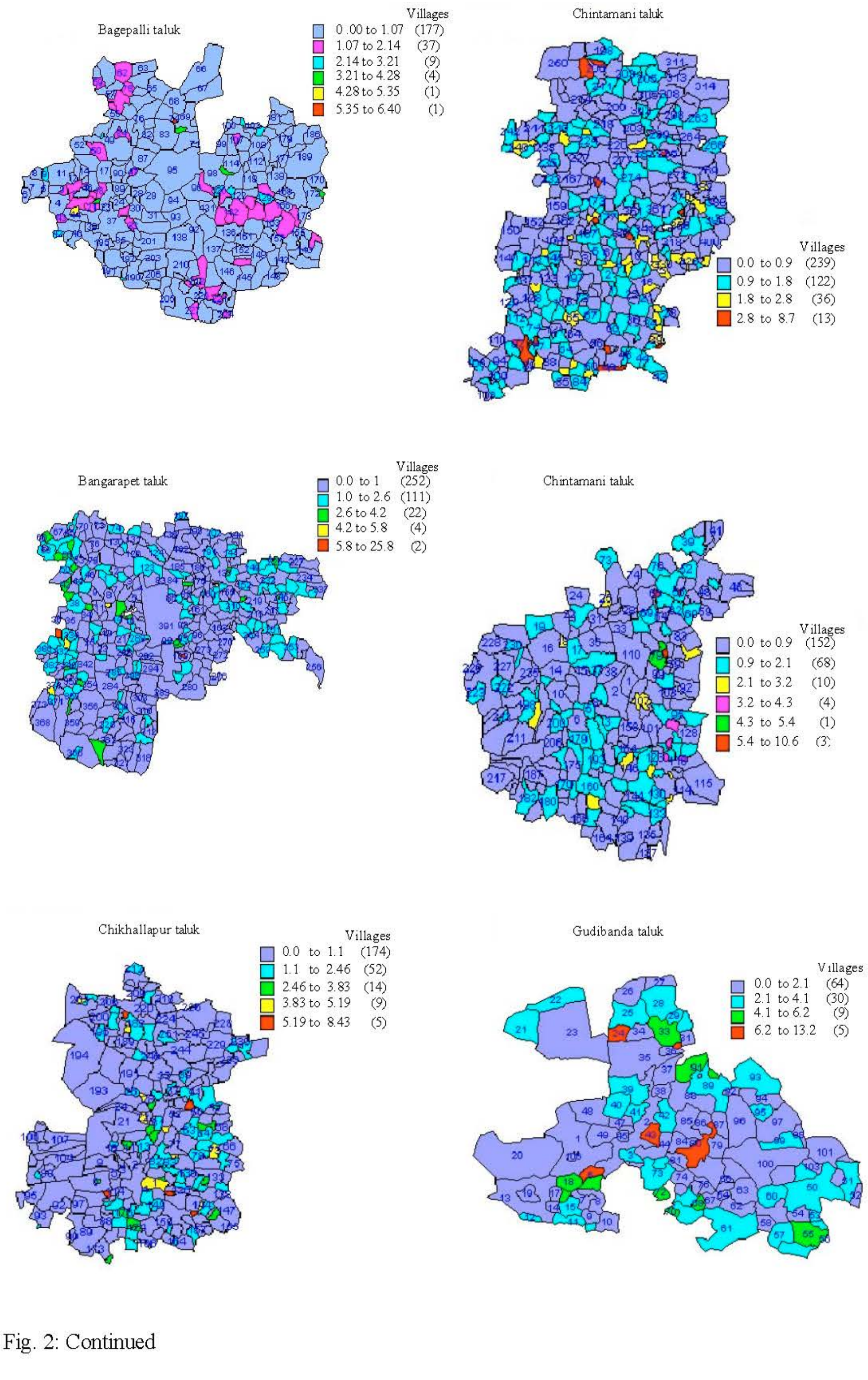

Fig. 2: Continued

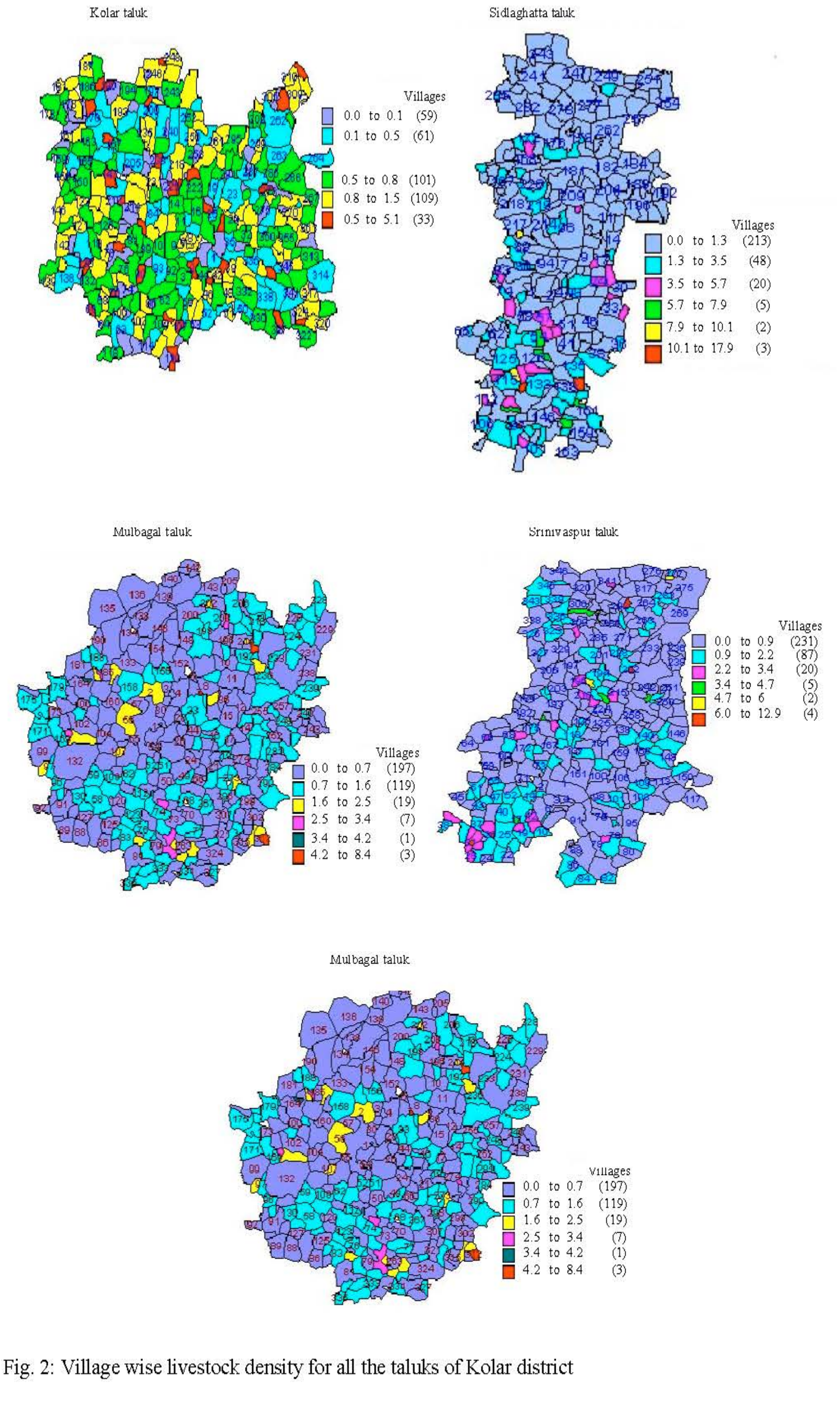

Fig. 2: Village wise livestock density for all the taluks of Kolar district

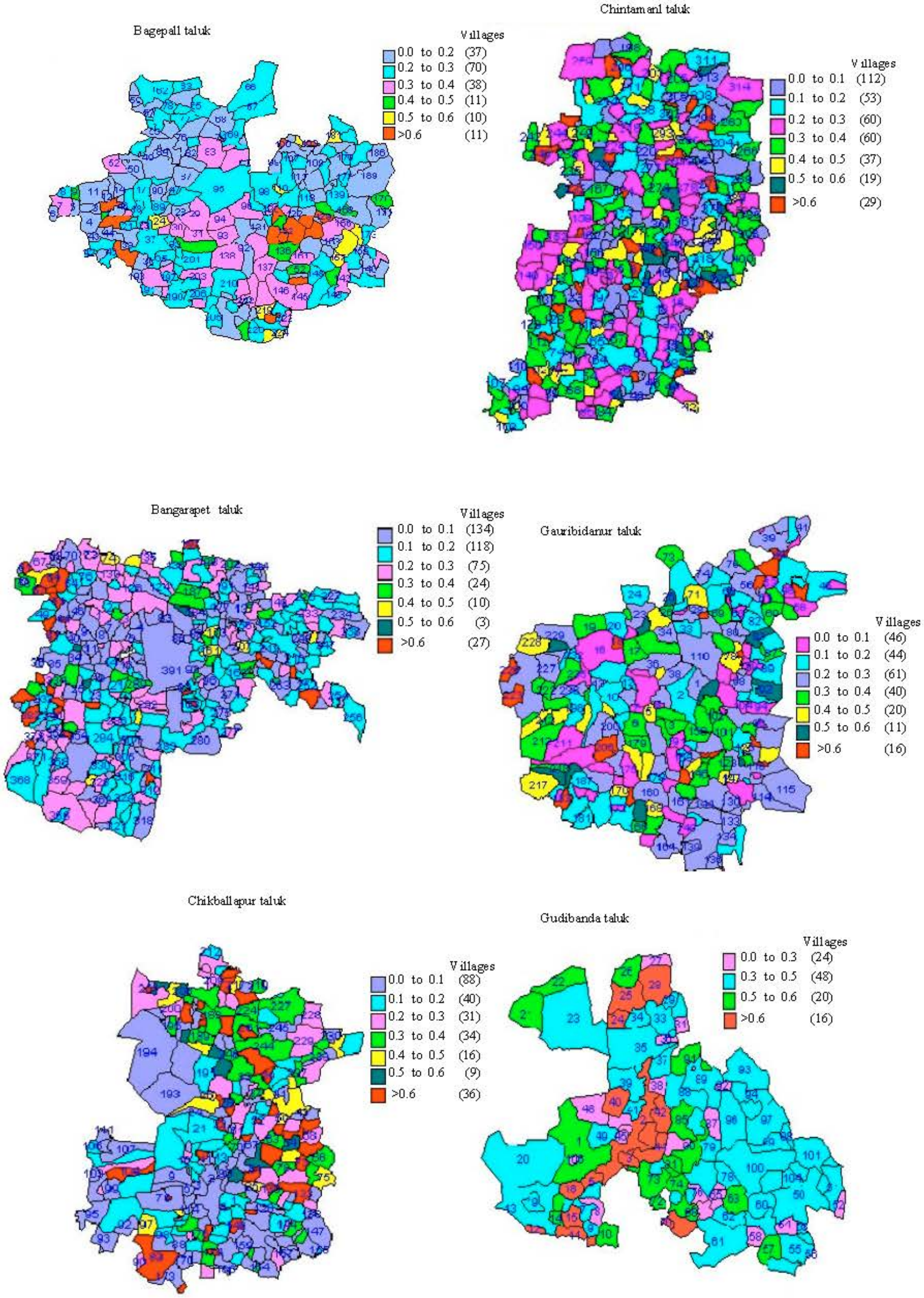

Fig. 3: Continued

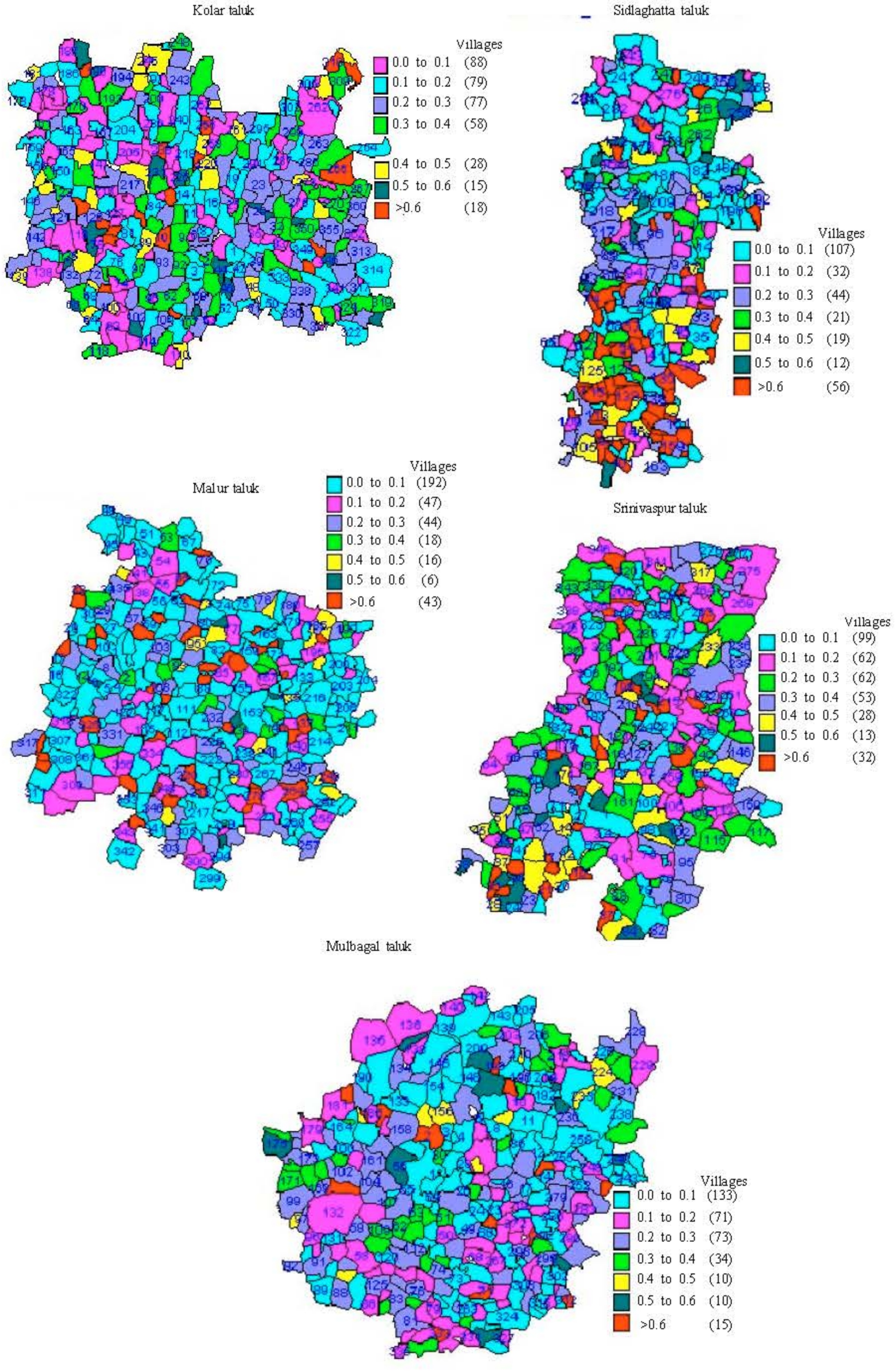

Fig. 3: Biogas potential considering reource (low)/demand (low) case for all the taluks in Kolar district

of stock-raising animals were estimated based on the villagewise livestock population (2005) for Kolar district, Karnataka State, India. This disaggregated approach helps in accurate assessment of resources in a region, which would be useful in successful dissemination of biogas plants

Study shows that the average livestock density of the district is 0.81. It ranges from 0.68 (Bagepalli, Malur), 0.70 (Kolar) to a maximum of 1.09 (Gauribidanur). Village wise livestock density for all the taluks of Kolar district is shown in Fig. 2. Talukwise livestock density (number of villages in each region) is listed Table 2. It shows that in Kolar district 2960 villages have average livestock density in the range of 0-2, 275 villages have density in the range of 2-4, 69 villages in the range of 4-6, 24 villages in the range of 6-8, 10 villages in the range of 8-10 and 7 villages have an average density greater than 10.

Dung yield from buffalo and cattle could be used optimally for energy (biogas generation) as well as manure. Table 3, lists the biogas potential (resources to demand ratio) with four different cases. Considering case 1, the domestic energy requirement met by biogas of more than 60% population are: 13 villages of Bagepalli taluk, 27 in Bangarpat, 36 in Chikballapur, 29 in Chintamani, 16 in Gauribidanur, 16 in Gudibanda, 18 in Kolar, 43 in Malur, 15 in Mulbagal, 56 in Sidlaghatta, 32 in Srinivasapur. In addition to animal residues, green leaves could be used as biogas feedstock. Biogas potential of all taluks for case one is represented in Fig. 3 and the analyses shows that biogas could be a viable option in many villages with integrated feedstock (dung, litter).

CONCLUSIONS

Bioenergy is one of the primary sources of fuel in India. The energy utilization in Karnataka considering all types of energy sources and sector wise consumption revealed that traditional fuels such as firewood (7.440 million tonnes of oil equivalent -43.6%), agro residue (1.510 million tonnes of oil equivalent -8.85%), biogas, cow dung (0.250 million tonnes of oil equivalent -1.47%) accounts for 53.20% of the total energy consumption in Karnataka. In rural areas the dependency on the bioenergy to meet the domestic energy requirements are as high as 80-85% (Ramachandra *et al*., 2000b). The production and use of biogas for domestic purposes can drastically reduce the depletion of natural resources like forests, which are otherwise the prominent and traditional source of energy for cooking and lighting. It removes dependence on forest and enhances greeneries leading to improved environment.

Kolar depends mainly on non-commercial forms of energy. Non-commercial energy constitutes 84%, met mainly by sources like firewood, agricultural residues and cowdung, while commercial energy share is 16%, met mainly by electricity, oil, etc. Availability of animal residues for biogas generation gives a viable alternative for cooking, lighting fuel and a useful fertiliser. Biogas technology is gaining additional upwind through new subsidy programmes for market incentive and development of renewable energies. Biogas potential in Kolar district is good (>60%). Analyses reveals that the domestic energy requirement can be met by biogas option in 301 villages in Kolar district for more than 60% population, 363 villages for 40-60% population, 1025 villages for 20-40% population and 1656 villages for less than 20% of the population. However to support the present livestock population fodder from agricultural residues is insufficient in these Taluks, which could be augmented by growing fodder crops during non-agriculture seasons. Various alternatives for improved utilisation of bio resources and to enhance bioresource stock in a region are fuel-efficient stoves, biogas, energy plantations, etc.

ACKNOWLEDGMENTS

I thank the Ministry of Science and Technology, Government of India and Indian Institute of Science for financial and infrastructure support to carry out this study. I am grateful to

Dr. H.N. Chanakya for useful suggestions during discussion. I thank Kolar district authorities for providing the data required for the analysis and the co-operation during field investigations.

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