Economic Viability of Soil Resource Mapping and its Use in Enhancing Farm Income — A Case Study of Garakahalli Micro Watershed in Karnataka

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Economic Viability of Soil Resource Mapping and its Use in Enhancing Farm Income - A Case study of Garakahalli Micro Watershed in Karnataka

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Abstract

Government priority in doubling of farm income of historically low yields in semiarid tracts of Karnataka is focused on enhancing the efficiency in crop productivity and natural resource use. Land resource inventory is basically aimed at deriving comprehensive information on natural resources for designing micro level land use planning and for enhancing land productivity and farm income. In view of this, an attempt was made to explore the economic viability of generating the soil survey information (1:12,500 scale) to minimize the cost of production thorough site specific nutrient management in Garakahalli microwatershed, Karnataka State. The results showed that the per hectare cost of improved method of soil survey (using PAN+LISS III imagery) is ₹ 264 over conventional method of soil survey costing ₹ 337. Improved method of soil survey can minimize the cost up to 22 per cent in field survey. The economic viability of soil map was assessed by estimating fertilizer requirement with and without soil information. The impact in change in fertilizer application of finger millet production on the basis of soil information can reduce application of nitrogen by 5265 kg and phosphorus by 4661 kg and improvement of 1054 quintal of yield with economic benefits of ₹ 8.43 lakhs in the watershed area of 527 ha. The study found that the benefits of soil survey in site specific fertilizer management in finger millet with the Benefit Cost Ratio 1:2.85 and the additional income due to soil management of ₹ 1600 per ha. The soil information is useful in minimizing fertilizer cost and in enhancing farm income. The investment in soil survey and fertility management is economically viable at watershed level.

Key words: Conventional method, Remote sensing method, Soil survey, Fertilizer misapplication, Economic viability

JEL Classification:

Introduction

Soil surveys are basically aimed at providing comprehensive information about soils of the area. Their broad objectives being both fundamental and applied in nature. Fundamentally, these surveys helps in understanding of soils as regards their genesis, development, classification and nomenclature. The applied part includes interpretation of soils data for use in agriculture, pasture development, recreation and other uses. It gives information needed for planning land use on sustained basis. Further, it helps in correlation of soils of known behavior and predicting their adaptability to various uses under defined sets of management practices. Soil survey thus forms the very basic for a planned land use the very basis for planned land use (AIS&LUS, 1970).

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Table 1. Kinds of mapping units and intensity of observation as per the scale of survey

Scale of mapping	Kind of mapping units	No. of observation per sq. km	
		Conventional	Remote sensing techniques
1:50,000	Soil series association	2	0.3-0.5
1: 25,000	Soil series associations and consociations	4	1-2
1: 12,500	Soil series, complex with phases	50	16-20
1:5000	Soil series, complex with phases	100-400	25-50

The detailed soil survey is undertaken in priority areas for development of villages/micro watersheds and farms etc. In this survey cadastral maps on the scale of 1: 8000 or larger are used as base map. The distance between field observations is 50 - 100 m and intensity of observations is 1-4 per ha.

The reconnaissance survey is undertaken to prepare soil resource inventory of a large area like taluk or district. Survey of India top sheets on 1:50,000 scales are used as base maps. The distance between observations is 500 m to 1 km and the number of observations are 1 per 25 - 100 ha (Sehgal, 1990).

The methodology adopted for soil resource mapping on 1:250,000 scale comprises a three tire approach: (i) Image interpretation, (ii) Field survey, mapping and soil analysis and (iii) Cartography and printing. The soil resource map prepared on 1:250,000 scale for all the states of country have been digitized using GIS. The resultant 1:250,000 scale map was categorically and cartographically generalized and 1:1 million scale soil map of the country was generated with association of subgroups as map units and printed and published.

Another type of map called exploratory soil maps are maps prepared on 1:1 million or smaller scale for the region which is under developed or newly brought into cultivation for estimating the occurrence of soil patterns. The data available both at spots and in map on the soils and the climate, vegetation, geology and landforms are gathered and studied. Unlike schematic soil maps, exploratory soil maps are made by identifying map units mainly by observation of soils within the area even though soil boundaries are drawn and compiled from other available sources.

In the modern method the soil survey was carried out using false colour composite of IRS 1C/1D PAN+LISS III imagery on 1:12,500 scale. Based on image interpretation elements like tone, texture, pattern, shape, size, association and drainage pattern and land use/land cover were used for delineating landforms and their further subdivisions. The profiles are studied in each photomorphic /physiographic unit which is extrapolated to other similar units. The mapping units are phases of soil series and complexes. The boundaries are delineated based on remotely sensed data with limited extensive traverses in the field.

The All India Soil and Land Use Survey Organization started using aerial photographs as base for mapping soils in the 1960's. It was the Central Arid Zone Research Institute (CAZRI) that started using aerial photographs with systematic photo interpretation for mapping soils in Rajasthan (Kolarkar and Abichandani, 1967; Abichandani, 1980). The aerial photo-interpretation techniques for soil survey gained momentum with the establishment of the then Indian Photo-Interpretation Institute at Dehra Dun in 1970.

In the recent years a study on standardization of methodology for large scale soil mapping using satellite data by NBSS & LUP (2005), reported that remote sensing data help in faster soil mapping and it saves time by 30 - 40 per cent, depending upon the terrain conditions and also helps in reducing the intensity of observations at different scales of mapping. They reported the number of observations needed for mapping soils at different scales by conventional and remote sensing techniques as given Table 1.

The satellite data were utilized in preparing small scale soil resource maps showing soil subgroups and their associations for about three decades (Mirajkar and Srinivasan, 1975; NRSA, 1976; 1978; 1979 ; 1981). The literature survey indicates that remote sensing data from Landsat MSS were used for mapping soils (NRSA, 1978; 1979; 1981) and degraded lands like eroded lands, ravinous lands (Kudrat *et al,*. 1977;

NRSA, 1981), salt affected soils (Venkataratnam and Rao 1977; Venkataratnam, 1980) and shifting cultivation areas (NRSA, 1979). Landsat TM, SPOT and IRS satellite data enabled to map soils at 1:50,000 scale at the level of association of soil series due to higher spatial and spectral resolutions.

In one of the major projects in Department of Space, Government of India, "Integrated Mission for Sustainable Development"- the soil mapping has been completed at 1:50,000 scale for about 175 districts / blocks in the country. With the availability of PAN data at 5.8 m spatial resolution from IRS-1C/1D satellites, soil resource mapping at 1:25,000 or larger scale has been attempted using PAN merged LISS-III data. The IKONOS data has the potential for farm level soil mapping (>1:10,000 or large).

The conventional soil surveys provide information on soils, are subjective, time- consuming and laborious. Modern remote sensing techniques have significantly contributed to speeding up soil survey programmes. The modern soil surveys using aerial photographs or satellite data considerable field work with respect to locating soil types and boundaries is reduced owing to higher spatial and spectral resolution with synoptic view. Remote sensing techniques have reduced field work to a considerable extent and soil boundaries are more precisely delineated than in conventional methods. This is true more so for medium and small scale soil surveys rather than detailed soil surveys.

Cost Benefits Analysis of Soil Survey

Klingebiel (1966) had stated that soil surveys have a wide range of uses that result in benefits which could repay costs in the first year. The paper had presented results of study undertaken by the US Soil Conservation Service and repowered to be an average benefit cost ratio (BCR) of 64:1 for soil surveys in low intensity ; 61:1 for soil surveys in medium intensity areas and of 123:1 for soil surveys in high intensity areas. Estimates were based on case histories and records of soil survey users.

Several researchers have developed soil survey quality indicators together with the evaluation of soil survey costs. Beckett and Burrough (1971) have compared different soil maps and related them to map precision standards. Bie and Beckett (1971) have evaluated the efficiency of soil maps by assessing their quality and production costs. Western (1978) has defined survey value as the balance between quality and cost, emphasizing that the term quality has different meanings for users and makers of soil surveys. He stated further that if soil survey quality could be measured by its economic benefits, survey value could be expressed as a ratio between the cost to carry out the soil survey and the benefits it produces. However, he affirmed that "it is in fact extremely difficult to quantify the benefits of soil survey" and that these benefits depend on the useful life of the survey. Beckett (1981) has reported that the cost of soil survey information increases with increase in precision and specificity of information. Dent and Young (1981) used a simplified example to illustrate methodologically that the economic benefits of a soil survey can be calculated by comparing the profitability from different management systems on each of a number of mapping units.

Thus several parameters have been used to measure the usefulness of soil survey: value, utility, quality and efficiency. In an open and competitive market, a good measure of the quality of a soil survey would be the economic benefits generated by the use of the information. These benefits would depend upon changes in production system resulting from the use of the information, which in turn would depend on the accuracy and precision of the information. The utility/ usefulness of soil survey information depends on the timely supply, details of soil information and its cost effectiveness in application. Providing precise information in shortest possible time with minimum cost is a challenge for a soil surveyor. The advancement in the methodology in soil mapping from traditional soil mapping techniques to improved methods is very helpful in saving time and cost in the soil survey programme.

A case study of Garakahalli micro watershed

In this study, the cost of soil survey was estimated using conventional and improved method in Garakahalli micro watershed representing Bangalore rural district of Karnataka State. The objective was to estimate different cost components involved in two soil survey methods and likely economic benefits for the farmers in the use of soil information in soil fertility management.

Detailed Soil Survey using Conventional Methodology

Garakahalli microwatershed (527 ha) is located in Garakahalli village, Channapatna taluk of Bangalore rural district, Karnataka. The detailed soil survey of Garkahalli micro-watershed was carried out using cadastral maps of 1:7920 scale. The preliminary traverse of the watershed was taken up to aquaint with field boundaries, field survey numbers and physiography. During the traverse based on geology, drainage pattern, slope characteristics, land use and, land forms, physiographic units were identified and initial legend was prepared.

In the selected transect, profiles were located at close intervals to take care of any change in the land features like break in slope, erosion, gravel and stones. In the selected sites, profiles were opened up to 180 cm or to the depth limited by rock or hard substratum and studied in detail for all their morphological and physical characteristics. The soil and site characteristics were recorded for all the profile sites on a standard proforma at per the guidelines given in USDA Soil Survey Manual (Soil Survey Staff 1993).

Based on soil-site characteristics, the soils were grouped into different soil series. Soil depth, texture, colour, gravel content, calcareousness, nature of substratum and kinds of horizon and its sequence were the major identifying characteristics for differentiating soil series in the watershed area. Based on the above characteristics, 14 soil series were identified and 85 phases of soil series (management units) were mapped and a soil map was prepared by the conventional method at 1: 7980 scale (Ramesh Kumar *et al,* 2002).

Modern Methodology

The False Colour Composite (FCC) of IRS 1C PAN+LISS III imagery on 1:12,500 scale was visually interpreted. The physiography map prepared during conventional survey was used in conjunction with the imagery. The Garkahalli watershed area was identified granite and granite gneiss landscape. This was divided into 5 physiographic units based on elevation and slope. They were further divided into 10 photomorphic units based on image characteristics. A physiography map was prepared through visual interpretation of satellite imagery at 1: 12,500 scale.

Before starting the field survey, all the phsyiographic units occurring in the watershed area were listed and its geographic distribution and frequency of occurrence.

The accuracy of image interpretation for physiography, geology and slope classes while traversing for transect studies were checked and corrections were incorporated where ever necessary.

While traversing the Garakahalli watershed area, along with image interpreted sheet and cadastral sheet, the transects were selected in such a way that it cut across as many physiographic units as possible. The locations of transects were marked on the interpreted sheet and all the profiles studied in the transect were numbered and marked. The relationship between image characteristics and physiographic or photomorphic units was developed.

The profiles in each transect were studied intensively at close intervals for accounting the soil variability that could be expected in each unit. On completion of each transect, the soil profile data were arrayed unit- wise and a preliminary legend was developed by translating each image interpretation-cum physiographic unit in terms of soils. Soils were classified up to series level (Soil Survey Staff, 1993; Soil Survey Staff, 1999) and mapped as phases of soil series. The detailed field investigation in the transects helped to ascertain the relationship between image characteristics and physiographic units, to test the validity of image interpretation and to establish the correlation between physiography and soils. About 12 series were identified and mapped with 30 phases of soil series. The phases were mapped by traversing all over the area.

Cost of Soil Survey

The cost of information increases with its precision and specificity in a soil resource programme. The details of cost involved in conventional and improved method are given in Table 2. The major cost items in a soil survey are salaries for field staff which accounted for ₹ 72253 (41%) conventional and ₹ 43352 (31%) in modern methods, respectively (Table 2). The daily allowances for field staff during field work accounted for 8.4 per cent and 6.5 per cent of the total cost of survey. The cost of satellite data, field materials like base map, field kit, etc works out to 0.3 per cent and

Table 2. Estimated cost on detailed soil survey by different methods in Garakahalli micro watershed, Karnataka

Cost of items	Cost of conventional method ([1])	% to total	Cost of improved method ([1])	% to total
Salaries for field staff	72250	40.7	43350	31.2
Daily allowances	15000	8.4	9000	6.5
Cost of satellite data, SOI top sheets and field material etc.	500	0.3	19000	13.7
Transport vehicle cost	6000	3.4	4000	2.9
Cost of labour for field survey	18750	10.6	7500	5.4
Laboratory analysis	17500	9.9	15000	10.8
GIS map making and printing	8000	4.5	8000	5.8
Report preparation and printing	10000	5.6	10000	7.2
Total cost	148000	83.3	115850	83.3
Overhead charges (including administration, electricity, rent on building) @ 20 % of total	29600	16.7	23170	16.7
Grand total ([1])	177600	100.0	139020	100.0
Per hectare cost of soil survey ([1])	337	264		

14 per cent in conventional and improved methods. Transport cost (POL) on field visit and sample collection accounts for 3.4 per cent and 2.9 per cent of total cost in conventional and improved method. Labour cost for profile digging and soil sample collection accounted for 10.6 per cent and 5.4 per cent of total cost in conventional and improved methods, respectively. The laboratory analysis of soil profile samples included sample preparation, chemicals and glassware cost which accounted for 10 per cent each in both conventional and improved methods.

The Geographic Information System (GIS) processing and map making involving digitization of base map and data inputting and map generation, accounted for 5 per cent in both the methods. In the total cost, the report preparation and printing of soil maps worked out to about 5 per cent and overhead charges worked out to 17 per cent of total cost of soil survey in both the methods.

The overall cost of detailed soil survey in conventional method was ₹ 337/ ha and ₹ 264/ha in modern method. The cost analysis indicated that improved method of soil survey can save about ₹ 73 per ha (22 %) over the conventional method of soil mapping.

Benefits of Soil Survey Information

The economic benefits of soil survey information depend on the period of utility of soil map. Beckett (1981) had reported that the useful life of soil survey is about 25 years. One of the valuable features of soil information is its repeated use across a range of applications, therefore soil information can create significant options for future use, but only if such information is appropriate to the needs, is retained and remains easily accessible to future users.

Soil information is an essential *input* into the types of datasets and informational products that are utilized by natural resource managers in their decision- making processes. A relatively broad interpretation of soil information for sustainable soil resource management might involve a shift away from a more productivity-oriented philosophy of land management to the collection and use of soil information for purposes that may include, but ultimately go beyond, concerns of agricultural productivity. Going further than this, a stronger view of 'sustainable' soil management might involve a paradigm shift under which landholders and policy makers would seek the following:

- Maintenance of soil productive capacity and reduction of inputs through soil fertility management,
- Minimization of off-site impacts like siltation of tanks and reservoirs,
- Minimization and prevention of soil degradation,
- Development of a soil monitoring and evaluation program for long-term planning and adaptive management,

Table 3. Fertility status of Garakahalli micro watershed

(Area in ha)

Items	Low	Medium	High
Nitrogen	492	35	0
Phosphorus	239	233	55
Potash	148	295	83

- Identification of appropriate land use(s) within a changing environment; and
- Marketing and branding of products that are adopting sustainable natural resource management practices.

The soil survey report consists of different thematic information like soil depth, texture, slope, erosion, gravelliness, soil pH, available soil macronutrients (nitrogen, phosphorus, potassium) and micronutrients (iron, zinc, copper and manganese), land capability classification, land irrigability classification , fertility capability classification and information on soil suitability (potential area) for different crop production.

In agriculture fertilizer is one of the costly inputs and has a significant contribution to production of additional food grains. The farmers apply fertilizers according to their cost and availability during the crop season without any consideration to inherent soil fertility. The agricultural extension agencies recommend the use of fertilizers based on a package of practices that are based on soil test results for a region.

Under these circumstances, soil variability within a field/watershed should be taken as a basis for fertilizer use recommendations. Therefore, an attempt was made to demonstrate the possible economic benefits for the farmers of Garakahalli Watershed by proper nutrient use pattern based on soil fertility status compared with the existing situation.

The fertility variability in Garakahalli micro-watershed is presented in Table 3. A large extent of area is under low nitrogen and phosphorus status.

In Garakahalli micro-watershed finger millet is the major crop grown. The present level of fertilizer use by farmers was taken for calculating fertilizer requirements without soil test. In the total watershed (527 ha), farmers were applying 65922 kg of NPK fertilizers and could produce 6851 quintals of finger millet (Table 4). When the fertilizer requirement for finger millet cultivation was calculated by considering the soil fertility status (with soil test), the total (NPK) fertilizer requirement came out to 69006 kg which can yield 7905 quintals. The change in fertilizer use (difference between soil test and without soil test) shows a scope for reducing nitrogen use (-5265 kg) and phosphorus (-4661 kg) and additional requirement of potash (+ 13009 kg) for the watershed area. The additional cost for implementing the site-specific fertilizer recommendation came outs to be ₹ 156558 for the watershed. With adoption of site specific fertilizer management, the finger millet production can be increased by 1045 quintals with an additional economic benefit of ₹ 843200 in the watershed.

Table 4. Fertilizer use pattern with and without soil information in finger millet cultivation

Soil fertility management	Fertilizers use pattern					Yield (quintal)/
	Items	Nitrogen	Phosphorus	Potash	Total(NPK)	income ([1]) level
			Without soil test			
Blanket level of fertilizer use	Quantity (kg)	37770	27578	574	65922	6851
	Value([1])	395075	441247	12637	848959	5480800
			With soil test			
Site specific application	Quantity (kg)	32506	22917	13584	69006	7905
	Value([1])	340008	366668	298841	1005517	6324000
			Differences in fertilize use			
Excess / Deficit	Quantity (kg)	-5265	-4661	13009	3084	1054
	Value([1])	-55067	-74579	286203	156558	843200

Table 5. Economic viability of soil survey information

Particulars	Cost on total watershed ([1])	[1] / ha
Cost of soil survey using improved method	139022	264
Cost of soil fertility management	156558	297
Total investment required (A+B)	295580	561
Additional income due to soil fertility management	843200	1600
Annual returns over investment in soil survey and nutrient management	547620	1039
Benefit Cost Ratio	2.85	2.85

The economic viability of soil survey is presented in Table 5. The per hectare cost of soil survey (improved method) is ₹ 264 and the per hectare additional cost for site specific fertility management (cost of fertilizers) is ₹ 297.

The investment required for site-specific nutrient management in the Garakahalli micro—watershed works out to be ₹ 561 per ha and the additional income due to soil management was found to be ₹ 1600. The annual net return over investment in soil survey programme was commuted as ₹ 1039 with a benefit cost ratio of 1:2.85.

Conclusions

1. Adoption of improved method of soil survey can minimize the cost of soil survey up to 22 Per cent.
2. Soil Survey information is useful in minimizing fertilizer misapplications.
3. The investment in soil survey and fertility management is economically viable.

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