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Economic Land Evaluation for Sustainable Land Management of Watersheds in Different Agro-Climatic Zones of Karnataka

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National Bureau of Soil Survey, Bangalore

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ECONOMIC LAND EVALUATION FOR SUSTAINABLE LAND MANAGEMENT OF WATERSHEDS IN DIFFERENT AGROCLIMATIC ZONES OF KARNATAKA

Volume II Database

National Bureau of Soil Survey and Land Use Planning
(Indian Council of Agricultural Research)
Amravati Road, Nagpur 440 010

Funded by

Indira Gandhi Institute of Development Research, Mumbai 400 065
"India's Environmental Management Capacity Building Project" (No. 212)

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about the NBSS&LUP

The National Bureau of Soil Survey and Land Use Planning(NBSS&LUP), Nagpur, a premier Institute of the Indian Council of Agricultural Research (ICAR), was set up in the year 1976 with the objective to prepare soil resource maps at state and district level and to provide research inputs in soil resource mapping, and its applications, land evaluation, land use planning, land resource management, and database management using GIS for optimising land use on different kinds of soils in the country. The Bureau has been engaged in carrying out agro-ecological and soil degradation mapping at the country, state and district level for qualitative assessment and monitoring the soil health towards viable land se planning. The research activities have resulted in identifying the soil potentials and problems, and the various applications of the soil surveys with the ultimate objective of sustainable agricultural development. The Bureau has the mandate to correlate and classify soils of the country and maintain a National Register of all the established soil series. The Institute is also imparting in-service training to staff of the soil survey agencies in the area of soil survey and land evaluation, soil survey interpretations for land use planning. The Bureau in collaboration with Dr.Panjabrao Deshmukh Krishi Vidyapeeth, Akola is running post-graduate, teaching and research programme in land resource management, leading to M.Sc. & Ph.D. degrees.

*The research of the Bureau has resulted in identifying various applications of soil surveys in education, planning and management. The publication "**Economic Land Evaluation for Sustainable Land Management of Watersheds in Different Agroclimatic Zones of Karnataka**" is one such example.*

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FOREWORD

Soil is one of the most important natural resources, and maintaining it in good health, is very much needed for meeting the increasing demand for food, fibre, fodder and fuel. It assumes greater significance in present situation wherein the scope of increasing the area further for cultivation is very limited. In view of this, the information on soils in respect of their extent on a particular landscape and their characteristics in terms of potentials and constraints is required so that the precious soil resource may be put to judicious use without allowing it to degrade further.

Proper identification of soil potential has been one of the key sectors in the planning and development processes. Hence, an appraisal of soil resources is a pre-requisite for planning a sustainable development. An appropriate soil resource inventorisation creates the awareness among the land users, planners, research workers and administrators in order to ensure the proper and effective utilisation of soil resource. The necessity of generating developmental plan at different level has been increasingly felt and therefore, thrust on proper land use planning through watershed management is given during the VIII Five Year Plan. The priority is being re-emphasised in X Plan formulation.

Soil has assumed multifunctionalities both as a source of livelihood gathering as well as environmental sink. Realising the needs for illustrating the soil and land resource inventories, the National Bureau of Soil Survey and Land Use Planning is generating the information on soils at the different scale (1:250,000, 1:50,000, 1:10,000 and 1:5,000). The report on "**Economic Land Evaluation for Sustainable Land Management of Watersheds in Different Agroclimatic Zones of Karnataka"** with soil maps is one of such important practical document brought out by the Regional Centre, NBSS&LUP, Bangalore. It provides information about the soils and their characteristics and potential for better use and management including agriculture and other allied aspects. At the

same time, it elaborates inherent potential and problems of soil likely to be encountered while exploring potential, and needed ameliorative measures. The data have been interpreted as per capability of soils and their suitability for different crops which could form the basis for sustainable agricultural practices and protection of soil resource from being degraded. The maps and data base will be of immense use in setting developmental activities and extension work to achieve rehabilitation of inmates and as a teaching and training tool for farm level workers.

I express my appreciation to Dr. K.S. Gajbhiye, Director and Dr. P. Krishnan, Head, Regional Centre, Bangalore for their sincere efforts in bringing out this model watershed soil database for optimising land use. I believe that this publication will help the user agencies, inmates of watersheds farmers in understanding the soils potential for different crops/cropping sequences towards increasing crop production to reach to a level of self-sufficiency and generating self employment throughout the year.

(J.S. SAMRA)

Deputy Director General (NRM)

ICAR, New Delhi

PREFACE

It is estimated that nearly 50 per cent of the land in the country, is suffering from different kinds of degradation problems due to its non-scientific and indiscriminate use. In addition to this, the shrinking land resources as evidenced by the availability of land area per human head is gradually diminishing. In Indian scenario, the land to man ratio was 0.50 ha in 1950, and it came down to 0.30 ha in 2000. If the situation continues, there would be chaos and turmoil leading to a lot of confrontation to provide basic need of human being for food, fibre, fodder and fuel. Hence, the land resource assessment is considered as a pre-requisite for development and management of natural resources for sustainable use by protecting the inherent production capacity of soil. At the same time, soil based data need to be disseminated very widely through education and training to create awareness about the value of the soil to the people so that, each one may be able to use the land judiciously, thereby protecting and preserving the soils for human posterity. The child of 21st century may not ask '*Here is the land but where is the soil*.'

This publication on "**Economic Land Evaluation for Sustainable Land Management of Watersheds in Different Agroclimatic Zones of Karnataka**" deals with the aspects connected with the generation of soil resource data and their economic interpretation to evolve the system for identifying salient problems and suggesting appropriate ameliorative measures thereon in order to ensure sustainable land use. The spatial distribution of each soil mapping unit occurring in the area is depicted in soil map. The soils were mapped into different mapping units as phases of soil series. Pedons belonging to each series were characterised in laboratory to understand the physical and chemical properties affecting the land use. The collected data were quantified for the suitability and extent of soil resources for different crops and the constraints were highlighted. This project characterise that farm level sustainable land management indicators which clearly bring out the issues of poverty in relation to soils.

The efforts made by Dr. S.C. Ramesh Kumar, Senior Scientist and his team in bringing out this publication and the cooperation and help extended by other staff of the Regional Centre, Bangalore are well appreciated. The report will be useful in planning soil based developmental activities and in training the farmers and young entrepreneur to make them aware to use the soils according to its potential for sustainability in agriculture.

(**K.S. GAJBHIYE**)

Director

NBSS&LUP, Nagpur

ABOUT THE PROJECT

The project was undertaken with the objective of increasing the capacity for application of economic principles and tools to environmental management in India. It was assisted by Indira Gandhi Institute of Development Research (IGIDR) by providing necessary funds for a period of 18 months with a budget outlay of Rs 14.98 lakhs. The project work was started in May 2000 and completed in June 2002.

The data was assessed, analysed, evaluated and synthesized into report form. The report has two parts. Part One consists of Chapters 1 to 5 describing the methodology followed in survey and summary results of biophysical and socio-economic accounting and evaluation. Part Two consists of the detailed database of biophysical and economic land evaluation of Garakahalli Nalatwad, Pettamanurahatti, and Molahalli. watersheds in Karnataka.

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Location and Extent. Garakahalli microwatershed is located in Garakahalli village, Channa-patna taluk of Bangalore Rural district, Karnataka and is 25 km east of Channapatna town. It is situated between 12°31′15″ to 12°31′36″ N latitude and 77°7′05″ to 77°7′54″ E longitude. The area of the watershed is 527 ha.

Climate. Garakahalli microwatershed falls in agroclimatic zone 5 (eastern dry zone) of Karna-taka. Climatic conditions in the watershed (Channapatna station) are given in Table 1.1, weekly normal rainfall and PET data in Table 1.2 and the water balance diagram in Fig. 1.1. Garakahalli area receives a mean annual rainfall of 821.0 mm with bimodal distribution. May and September are the two peak rainy months. The frequency of drought is 1 to 2 in a decade. The length of the main growing season is 120 to 150 days during August to November. The maximum probability of 11 per cent for start of the growing season is for the 33rd, 37th and 38th weeks. The end of the growing season varies from the 46th to the 51st week with maximum probability of 18.52 per cent for the 48th and 49th weeks, followed by 50th and 51st week with probability of 14.81 per cent. The mean maximum temperature during July to November ranges from 26.3 to 27.6 °C and mean minimum temperature remains between 17.2 and 19.2 °C so that there is no limitation for most of the crops grown in the area.

Geology. The watershed is on granite and granite-gneiss over which residual soils have formed.

Fig. 1.1 Water balance in Garakahalli microwatershed (Channapatna station).

Table 1.1 Climatic **conditions — Garakahalli microwatershed (Channapatna station)**

Month	Mean daily temperature		Monthly rainfall	Relative humidity	
	Maximum	Minimum		0830	1730
	°C		mm	%	
January	26.9	15.0	2.5	77	40
February	29.7	16.5	7.1	67	29
March	32.3	19.0	10.4	63	24
April	33.4	21.2	46.7	70	34
May	32.7	21.1	126.7	75	46
June	28.9	19.7	68.6	82	62
July	27.2	19.2	75.2	86	68
August	27.3	19.2	117.3	86	66
September	27.6	18.9	149.6	85	62
October	27.5	18.9	160.0	83	64
November	26.3	17.2	62.5	78	59
December	25.7	15.3	12.9	78	51
Annual	28.8	18.4	839.5	77	50

Source: IMD (1984)

Table 1.2 Normal rainfall and PET data — Garakahalli watershed (Channapatna station)

Month	Dates	Week No.	Rainfall	PET
			mm	
January	1–7	1	0.0	26.4
January	8–14	2	0.0	26.4
January	15–21	3	2.5	26.4
January	22–28	4	0.0	26.4
Jan. – Feb.	29–31, 1–4	5	0.0	29.9
February	5–11	6	0.0	32.5
February	12–18	7	1.2	32.5
February	19–25	8	5.2	32.5
Feb. – Mar.	26–28, 1–4	9	1.3	35.3
March	5–11	10	4.2	37.5
March	12–18	11	2.2	37.5
March	19–25	12	3.6	37.5
Mar. –Apr.	26–31, 1	13	4.1	37.4
April	2–8	14	5.8	36.9

April	9–15	15	10.3	36.9
April	16–22	16	7.9	36.9
April	23–29	17	16.3	36.9
Apr. – May	30, 1–6	18	21.2	35.7
May	7–13	19	19.3	35.5
May	14–20	20	33.4	35.5
May	21–27	21	38.3	35.5
May – Jun.	28–31, 1–3	22	26.7	33.0
June	4–10	23	30.5	29.6
June	11–17	24	16.4	29.6
June	18–24	25	14.1	29.6
Jun. – Jul.	25–30 & 1	26	6.7	29.1
July	2–8	27	13.2	26.2
July	9–15	28	13.0	26.2
July	16–22	29	14.2	26.2
July	23–29	30	20.4	26.2
Jul. – Aug.	30–31, 1–4	31	21.8	25.9
August	6–12	32	12.1	25.7
August	13–19	33	14.3	25.7
August	20–26	34	28.5	25.7
Aug. – Sep.	27–31; 1–2	35	32.0	25.7
September	3–9	36	18.8	25.4
September	10–16	37	42.6	25.4
September	17–23	38	50.6	25.4
September	24–30	39	47.6	25.4
October	1–7	40	53.8	23.7
October	8–14	41	38.9	23.7
October	15–21	42	28.8	23.7
October	22–28	43	29.2	23.7
Oct. – Nov.	29–31, 1–4	44	17.9	23.2
November	5–11	45	15.8	22.9
November	12–18	46	12.1	22.9
November	19–25	47	7.0	22.9
Nov. – Dec.	26–30, 1–2	48	2.7	23.0
December	3–9	49	5.6	23.3
December	10–16	50	6.0	23.3
December	17–23	51	1.8	23.3
December	24–31	52	1.3	23.3
Total			821.0	1496.9

Source: DMC (1997)

Physiography. The area consists of very gently sloping and gently sloping lands with elevation ranging from 895 m to 900 m above MSL. The slope ranges from <1 per cent to about 8 per cent. The area is drained to a stream, which joins the Garakahalli tank. The microwatershed is more or less triangular in shape.
Vegetation and present land use. Most of the area is under cultivation; hence there is very little natural vegetation. *Ficus* spp., *jali*, neem, *Lantana* spp., eucalyptus, tamarind, and pongamia are found along the streams and on bunds.

The area of the microwatershed is presently under rainfed agriculture. The important crops grown are mulberry, groundnut, finger millet, horsegram, and sorghum. Irrigation from tubewells has enabled cultivation of irrigated mulberry, banana and rice.

2. THE SOILS

During detailed soil survey of the microwatershed, 14 soil series were identified on the basis of identifying characteristics observed in the field (Table 2.1). The morphological features determined for each of the series are presented in Table 2.2. These series were mapped as 85 phases on the basis of variations in surface soil texture, slope and erosion status as determined at the profile site locations shown in Fig. 2.1. The soil series map of the microwatershed is presented in Fig. 2.2 and the detailed soil map of phases in Fig. 2.3.

2.1 Description of the Soils

A brief description of the 14 soil series is given below.

Series A: **loamy-skeletal, mixed, isohyperthermic, Lithic Ustorthent (2.08 ha, 0.39%)**

Soils of series A (Fig. 2.4a) are very shallow (<25 cm deep), welldrained or somewhat excessively drained, dark brown to dark reddish brown, gravelly sandy loam soils with 60 to 70 per cent gravel and stones. They are formed on weathered granite and occur on moderately slo-ping and moderately steeply sloping (10–25% slope) mounds. These soils are moderately eroded. They are mostly under grasses and scrub forest.

The soils are slightly acid (pH 6.3). Clay content is 17.8 per cent and cation exchange capacity 7.0 cmol (+) kg^{-1} with base saturation of 86 per cent. The estimated available water capacity is very low (<50 mm). Organic carbon content (1.21%) is high.

The following phase of series A was mapped in the watershed.

Ag2hD2St4: Series A with gravelly sandy clay loam surface soil on moderately sloping (8–15% slope) mounds with moderate erosion; gravelly (15–35%) and very stony (15–90%) on the surface.

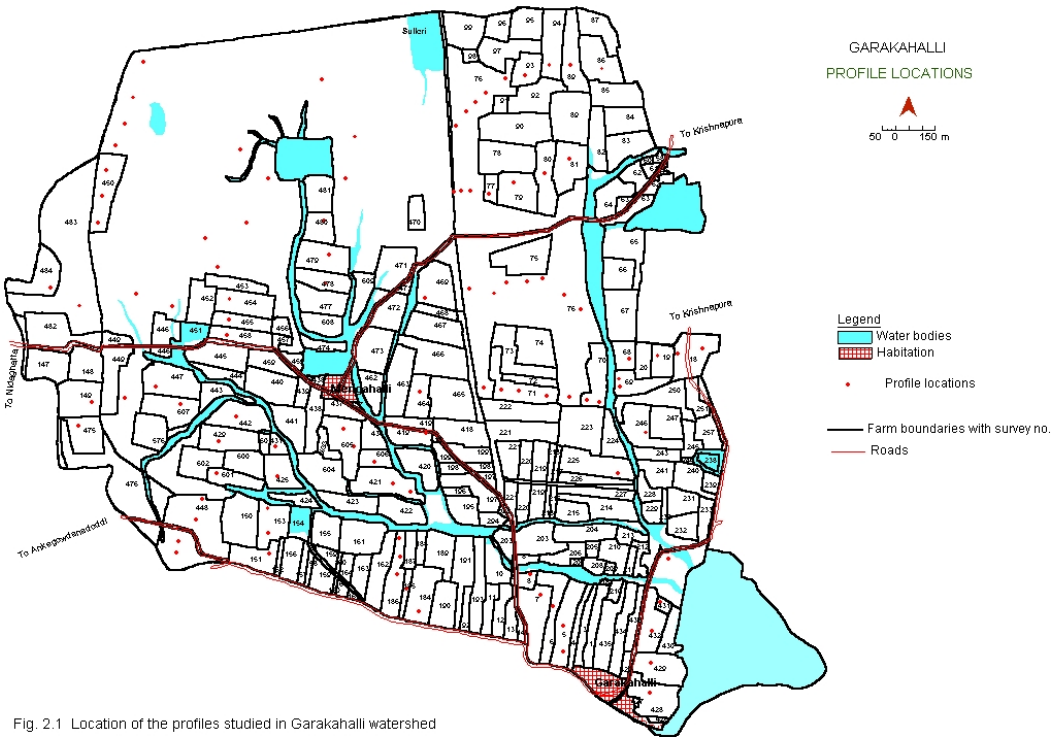

Fig. 2.1 Location of the profiles studied in Garakahalli watershed

Series B: fine, mixed, isohyperthermic, Typic Rhodustalf (7.35 ha, 1.39%)

Soils of series B (Fig. 2.4b) are moderately shallow (50–75 cm deep), welldrained soils with dark red to red sandy clay loam to sandy loam surface soils and dark red to dark reddish brown sandy clay to sandy clay loam subsoils with 5–30 per cent quartz gravel and are developed on weathered granite. They occur on very gently sloping (1–3% slope) uplands and are generally cultivated to rainfed crops such as finger millet*)*, *Dolichos lablab,* niger and fodder sorghum.. These soils are slightly eroded.

The soils are neutral to mildly alkaline (pH 6.8 –7.5). Clay content is 17.8 per cent in the surface layer and 26.1 to 41.6 per cent in the subsoil. Cation exchange capacity is 9.9 cmol (+) kg^{-1} in the surface soil and 12.2 to 16.8 cmol (+) kg^{-1} in the subsoil. The base saturation is 72 per cent in the surface soil and 76 per cent in the subsoil. The estimated available water capacity is medium (100–150 mm). Organic carbon content (0.37%) is low.

The following phases of series B were mapped in the watershed.

BcB1: Series B with sandy loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

BmB1: Series B with clayey surface soil on very gently sloping (1–3% slope) uplands with slight erosion.

Series C: fine, mixed, isohyperthermic, Typic Rhodustalf (50.61 ha, 9.61%)

The soils of series C (Fig. 2.5a) are moderately deep (75–100 cm deep), welldrained soils with yellowish red to dark reddish brown, sandy loam to loamy sand and sandy clay loam surface soils and dark brown to dark red, sandy clay to clay subsoils with 0–30 per cent quartz gravel and are developed on weathered granite. They occur on very gently sloping and gently sloping (1–5% slope) uplands. These soils are slightly or moderately eroded and are mostly cultivated to rainfed *kharif* crops.

The soils are neutral acid (pH 6.6–6.8). Clay content is 16.6 per cent in surface soil and 35–40 per cent in the subsoil. The cation exchange capacity is 10.3 cmol (+) kg^{-1} in the surface soil and 19.0 cmol (+) kg^{-1} in the subsoil. The base saturation is 81 per cent in both surface and subsurface soils. The organic carbon content (0.19%) is low. The estimated available water capacity is medium (100–150 mm).

The following phases of series C were mapped in the watershed.

CbB1: Series C with loamy sand surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

CcB1: Series C with sandy loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

CcC2: Series C with sandy loam surface soil on gently sloping (3–5% slope) uplands with moderate erosion;

Cg1bC1: Series C with loamy sand surface soil (<15% gravel) on gently sloping (3–5% slope) uplands with sligth erosion;

Cg1hB1: Series C with sandy clay loam surface soil (<15% gravel) on very gently sloping (1–3% slope) uplands with slight erosion;

Cg2fB1: Series C with gravelly clay loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

ChB1: Series C with sandy clay loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

CiC1: Series C with sandy clay surface soil on gently sloping (3–8% slope) uplands with slight erosion.

Series D: fine, mixed, isohyperthermic, Typic Rhodustalf (8.61 ha, 1.64%)

The soils of series D (Fig. 2.5b) are moderately deep (75–100 cm) and welldrained, and have dark red to red, loamy sand or sandy loam surface soils and dark red, gravelly clay or clay subsoils with 10–70 per cent quartz gravel between 15 and 60 cm depth. They occur on very gently sloping and gently sloping (1–8% slope) uplands and are formed on weathered granite. These soils are slightly eroded and are mostly cultivated to rainfed *kharif* crops.

The soils are neutral (pH. 7.2–7.3). Clay content is 32.5 per cent in the surface soil and increases with depth (38.6 to 43.8%) down the profile. The cation exchange capacity is 13.2 cmol (+) kg^{-1} in the surface soil and 15.6 to 17.1 cmol (+) kg^{-1} in the subsoil. Base saturation is 67 per cent in the surface soil and 61–64 per cent in the subsoil. Organic carbon content (0.45%) is low and decreases with depth. The estimated available water capacity is medium (100–150 mm).

The following phases of series D were mapped in the watershed.

Dg1bB1: Series D with loamy sand surface soil with <15 per cent gravel on very gently sloping (1–3% slope) uplands with slight erosion;

Dg1bB1St3: Series D with loamy sand surface soil <15 per cent gravel on very gently sloping (1–3% slope) uplands with slight erosion; 3–5 per cent stones on the surface;

Dg1cC1: Series D with sandy loam surface soil <15 per cent gravel on gently sloping (3–8% slope) uplands with slight erosion;

DmB1: Series D with clayey surface soil on very gently sloping (0–1% slope) uplands with slight erosion.

Series E: fine loamy, mixed, isohyperthermic, Typic Haplustalf (2.87 ha, 4.14%)

Soils of series E (Fig. 2.6a) are moderately deep (75–100 cm) and welldrained, and have reddish brown to red and dark red, sandy loam or sandy clay loam surface soils and strong brown to dark red gravelly sandy clay loam subsoils with 15–35 per cent quartz gravel in the sub-soil. They occur on very gently sloping and gently sloping (1–8% slope) uplands and are formed on weathered granite. These soils are slightly eroded or moderately eroded and are generally cultivated to rainfed *kharif* crops.

The soils are slightly acid (pH 6.4) or neutral (pH 6.8–7.1). The clay content is 23.2 per cent in the surface soil and 24.8 to 31.3 per cent in the subsoil. Cation exchange capacity is 10.1 cmol (+) kg^{-1} in the surface layer and 11.6 cmol (+) kg^{-1} in the subsoil. The base saturation is 53 per cent in the surface soil and ranges from 51 to 61 per cent in the subsoil. Organic carbon content (0.31%) is low. The estimated available water capacity is medium (100–150 mm).

The following phases of series E were mapped in the watershed.

EbB1: Series E with loamy sand surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

Eg1hB1–R: Series E with sandy clay loam surface soil with <15 per cent gravel on very gently sloping (1–3% slope) uplands with slight erosion, associated with rock outcrops in complex pattern;

Eg1iB1: Series E with sandy clay surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

Eg1cB1St3: Series E with sandy loam surface soil with 15–35 per cent gravel on very gently sloping uplands with slight erosion; 3–15 per cent stones on the surface;

Eg2cC2St4: Series E with sandy loam surface soil with 15–35 per cent gravel on gently sloping (3–9% slope) uplands with moderate erosion; 15–90 per cent stones on the surface;

EmB1: Series E with clay surface soil on very gently sloping (1–3% slope) uplands with slight erosion.

Series F: fine, mixed, isohyperthermic, Typic Rhodustalf (38.00 ha, 7.21%)

Soils of series F (Fig. 2.6b) are deep (100–150 cm) and welldrained, and have strong brown to red, loamy sand, sandy loam or sandy clay loam surface soils and brown to yellowish red and dark red sandy clay or gravelly sandy clay subsoils with more than 35 per cent quartz gravel. They are formed on weathered granite and occur on very gently sloping (1–3% slope) uplands. These soils are slightly eroded. They are generally cultivated to rainfed *kharif* crops, but at places are irrigated from borewells for banana and coconut, and vegetables such as brinjal.

The soils are slightly acid or neutral (pH 6.3–6.9). Clay content is 34.2 per cent in the surface soil and increases with depth (41 to 46.6%) in the subsoil. The cation exchange capacity is 3.6 cmol (+) kg^{-1} in the surface and ranges from 11.5 to 12.9 cmol (+) kg^{-1} in the subsoil. Base saturation is 81 per cent in the surface soil and lower (57–63%) in the subsoil. Organic carbon content (0.28%) is low. The estimated available water capacity is medium (100–150 mm).

The following phases of series F were mapped in the watershed.

FbB1: Series F with loamy sand surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

FcB1: Series F with sandy loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

FhB1: Series F with sandy clay loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

FiB1: Series F with sandy clay loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion.

Series G; fine-loamy, mixed, isohyperthermic, Typic Rhodustalf (27.03 ha, 5.13%)

Soils of series G (Fig. 2.7a) are deep (100–150 cm) and welldrained, and have dark reddish brown to yellowish red, loamy sand, sandy loam or sandy clay loam surface soils and reddish brown to dark red, gravelly sandy clay loam subsoils with 15–40 per cent quartz gravel. They occur on very gently sloping to moderately steeply sloping (1–30% slope) uplands. They are formed on weathered granite and are slightly eroded or moderately eroded. These soils are under grass and scrub forest, but at places are cultivated to rainfed *kharif* crops.

The soils are slightly acid or neutral (pH 6.2–6.7). Clay content is 10.2 per cent in the surface soil and 19.6–27.2 per cent in the subsoil. Cation exchange capacity is 7.0 cmol (+) kg^{-1} in the surface layer and 7.5–9.0 cmol (+) kg^{-1} in the subsoil. Base saturation is 69 per cent in surface soil and ranges from 67 to 100 per cent in the subsoil. Organic carbon content is medium (0.76%) in the surface soil and decreases regularly with depth. The estimated available water capacity is medium (100–150 mm).

The following phases of series G were mapped in the watershed.

GbB1: Series G with loamy sand surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

GbB2: Series G with loamy sand surface soil on very gently sloping (1–3% slope) uplands with moderate erosion;

GbC2St3–R: Series G with loamy sand surface soil on gently sloping (3–8% slope) uplands with moderate erosion, 3–15 per cent stones spread on the surface, associated with rock outcrops in complex pattern;

GcB1: Series G with sandy loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

Gg1cE3St4: Series G with sandy loam surface soil on with <15 per cent gravel on moderately steeply sloping (15–30% slope) uplands with severe erosion, 15–90 per cent surface stones;

Gg1hC1St3: Series G with sandy clay loam surface soil with <15 per cent gravel on very gently sloping (3–8% slope) uplands with slight erosion, 3–15 per cent stones on the surface;

Gg1hE3St4: Series G with sandy clay loam surface soil with <15 per cent gravel on very gently sloping (1–3% slope) uplands with slight erosion, 15–90 per cent stones on the surface;

Gg1iC1: Series G with sandy clay surface soil with <15 per cent gravel on very gently sloping (3–8% slope) uplands with slight erosion,

Gg2cD2St4–R: Series G with gravelly (15–35% gravel) sandy loam surface soil on moderately sloping (8–15% slope) uplands with moderate erosion, 15–90 per cent stones on the surface; associated with rock outcrops in complex pattern;

Gg2hC2St3: Series G with gravelly (15–35% gravel) sandy clay loam surface soil on very gently sloping (3–8% slope) uplands with moderate erosion, 3–15 per cent stones on the surface.

Series H: clayey-skeletal, mixed, isohyperthermic, Kandic Paleustalf (48.59 ha, 9.22%)

Soils of series H (Fig. 2.7b) are deep (100–150 cm) and welldrained, and have dark brown to red, loamy sand, sandy loam or sandy clay loam surface soils and dark red to dark reddish brown, gravelly sandy clay loam or gravelly sandy clay subsoils with 15–60 per cent quartz gravel. They occur on very gently sloping to

moderately sloping (1–15% slope) uplands, are formed on weathered granite and are slightly eroded or moderately eroded. These soils are generally cultivated to rainfed crops, but at places are under grass.

The soils are medium acid to neutral (pH 5.8–6.7). Clay content is 21.5 per cent in the surface soil and increases with depth down the profile (31–41.9%). The cation exchange capacity is 6.3 cmol (+) kg^{-1} in the surface soil and 8.3–16.6 cmol (+) kg^{-1} in the subsoil. Base saturation is 51 per cent in the surface soil and ranges in the subsoil from 48 to 93 per cent. Organic carbon content (0.50%) is low. The estimated available water capacity is low (50–100 mm).

The following phases of series H were mapped in the watershed.

HbB1: Series H with loamy sand surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

HcB1: Series H with sandy loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

HcB1St3: Series H with sandy loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

Hg1bB1: Series H with loamy sand surface soil with <15 per cent gravel on very gently sloping (1–3% slope) uplands with slight erosion;

Hg1cD2St4: Series H with sandy loam surface soil with <15 per cent gravel on moderately sloping (8–15% slope) uplands with moderate erosion, 15–90 per cent stones on the surface;

Hg1hB1: Series H with sandy clay loam surface soil with <15 per cent gravel on very gently sloping (1–3% slope) uplands with slight erosion;

Hg1hD2St4: Series H with sandy clay loam surface soil with <15 per cent gravel on moderately sloping (8–15% slope) uplands with moderate erosion, 15–90 per cent stones on the surface;

Hg1iB1: Series H with sandy clay surface soil with <15 per cent gravel on very gently sloping (1–3% slope) uplands with slight erosion;

Hg1iC1: Series H with sandy clay surface soil with <15 per cent gravel on gently sloping (3–8% slope) uplands with slight erosion;

Hg2bB1: Series H with loamy sand surface soil with 15–35 per cent gravel on very gently sloping (1–3% slope) uplands with slight erosion;

Hg2cD2St3: Series H with gravelly (15–35% gravel) sandy loam surface on moderately sloping (8–15% slope) uplands with moderate erosion, 3–15 per cent stones on the surface;

Hg2hD2St4: Series H with gravelly (15–35% gravel) sandy loam surface soil on moderately sloping (8–15% slope) uplands with moderate erosion, 15–90 per cent stones on the surface;

Hg2iC1: Series H with gravelly (15–35% gravel) sandy clay surface soil on gently sloping (3–8% slope) uplands with slight erosion;

HhB1: Series H with sandy clay loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

HmC1St3: Series H with clay surface soil on gently sloping (3–8% slope) uplands with slight erosion, 3–15 per cent stones on the surface.

Series I: fine, mixed, isohyperthermic, Typic Rhodustalf (29.96 ha, 5.68%)

Soils of series I (Fig. 2.8a) are deep (100–150 cm) and welldrained, and have dark brown to dark reddish brown, sandy loam, sandy clay loam or sandy clay surface soils and dark reddish brown, sandy clay loam subsoils. They occur on very gently sloping or on gently sloping (1–8% slope) uplands, are formed on weathered granite, and are slightly eroded or moderately eroded. These soils are cultivated to rainfed *kharif* crops.

The soils are slightly acid or neutral (pH 6.4–6.9). Clay content is 19.2 per cent in the surface soil and 24.5–31.6 per cent in the subsoil. Cation exchange capacity is 6.0 cmol (+) kg^{-1} in the surface soil and ranges from 9.6 to 11.9 cmol (+) kg^{-1} in the subsoil. Base saturation is 72 per cent in the surface layer and increases

in the subsoil. Organic carbon content (0.24%) is low. The estimated available water capacity is medium (100–150 mm).

The following phases of series I were mapped in the watershed.

IbC1: Series I with loamy sand surface soil on gently sloping (3–8% slope) uplands with slight erosion;

IcB1:Series I with sandy loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

IcC1: Series I with sandy loam surface soil on gently sloping (3–8% slope) uplands with slight erosion;

Ig1hC1: Series I with sandy clay loam surface soil with <15 per cent gravel on gently sloping (3–8% slope) uplands with slight erosion;

Ig2hC2St3: Series I with gravelly (15–35% gravel) sandy clay loam surface soil on gently sloping (3–8% slope) uplands with moderate erosion, 3–15 per cent stones on the surface;

IhB1: Series I with sandy clay loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

IiB1: Series I with sandy clay surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

IiC2: Series I with sandy clay surface soil on gently sloping (3–8% slope) uplands with moderate erosion;

ImB1: Series I with clay surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

ImB2: Series I with clay surface soil on very gently sloping (1–3% slope) uplands with moderate erosion.

Series J: fine, mixed, isohyperthermic, Typic Haplustalf (10.66 ha, 2.02%)

Soils of series J (Fig. 2.8b) are deep (100–150 cm) and welldrained, and have dark brown to dark reddish brown, sandy loam, sandy clay loam or sandy clay surface soils and reddish brown to dark brown, sandy clay loam and sandy clay subsoils. They occur on very gently sloping to moderately sloping (1–15% slope) lands, are formed on weathered granite and are slightly or moderately eroded. These soils are cultivated to rainfed *kharif* crops.

The soils are moderately alkaline (pH 8.1). Clay contetn is 16.9 per cent in the surface soil and 21.7–40.9 per cent in the subsoil. Cation exchange capacity is 10.5 cmol (+) kg^{-1} in the surface soil and ranges from 9.4 to 16.8 cmol (+) kg^{-1} in the subsoil. Base saturation is 92 per cent in the surface soil and 85 to 91 per cent in the subsoil. Organic carbon content (0.46%) is low. The estimated available water capacity is medium (100–150 mm).

The following phases of series J were mapped in the watershed.

Jg1hD2St3: Series J with sandy clay loam surface soil with <15 per cent gravel on moderately sloping (8–15% slope) lands with moderate erosion, 3–15 per cent stones on the surface;

JhB1: Series J with sandy clay loam surface soil on very gently sloping (1–3% slope) lands with slight erosion;

JiB1: Series J with sandy clay surface soil on very gently sloping (1–3% slope) lands with slight erosion.

Series K: fine, mixed, isohyperthermic, Rhodic Paleustalf (146.38 ha, 27.76%)

The soils of series K (Fig. 2.9a) are very deep (>150 cm) and welldrained, and have dark brown to red and reddish brown, loamy sand, sandy loam or sandy clay loam surface soils and dark red to dark reddish brown, sandy clay loam, sandy clay and gravelly sandy clay loam subsoils. They occur on very gently sloping to moderately sloping (1–15% slope) uplands, are formed on weathered

granite and are slightly or moderately eroded. These soils are mostly cultivated to rainfed *kharif* crops.

The soils are medium acid to neutral (pH 5.9–6.9). Clay content is 13.5 per cent in the surface soil and ranges from 32.3–42.0 per cent in the subsoil. The cation exchange capacity is 5.5 cmol (+) kg^{-1}in the surface soil and increases from 13.5 to 18.0 cmol (+) kg^{-1} with depth. Base saturation is 49 per cent in the surface soil and 47–56 per cent in the subsoil. Organic carbon content (0.41%) is low. The estimated available water capacity is medium (100–150 mm).

The following phases of Series K were mapped in the watershed.

KbB1: Series K with loamy sand surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

KbC2: Series K with loamy sand surface soil on gently sloping (3–8% slope) uplands with moderate erosion;

KcB1: Series K with sandy loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

KcC1: Series K with sandy loam surface soil on gently sloping (3–8% slope) uplands with slight erosion;

Kg1cB1: Series K with sandy loam surface soil with <15 per cent gravel on very gently sloping (1–3% slope) uplands with slight erosion;

Kg1hB1: Series K with sandy loam surface soil with <15 per cent gravel on very gently sloping (1–3% slope) uplands with slight erosion;

Kg1hC2St4–R: Series K with sandy clay loam surface soil with <15 per cent gravel on gently sloping (3–8% slope) uplands with moderate erosion, 15–90 per cent stones on the surface, associated with rock outcrops in complex pattern;

Kg2hD2St4–R: Series K with gravelly (15–35% gravel) sandy clay loam surface soil on moderately sloping (8–15% slope) uplands with moderate erosion, 15–90 per cent stones on the surface, associated with rock outcrops in complex pattern;

KhB1: Series K with sandy loam surface soil very gently sloping (1–3% slope) uplands with slight erosion;

KhC1: Series K with sandy clay loam surface soil on gently sloping (3–8% slope) uplands with slight erosion;

KhD2: Series K with sandy clay loam surface soil on moderately sloping (8–15% slope) uplands with moderate erosion;

KhD2St3: Series K with sandy clay loam surface soil on moderately sloping (8–15% slope) uplands with moderate erosion, 3–15 per cent stones on the surface;

KiC1: Series K with sandy clay surface soil on gently sloping (3–8% slope) uplands with slight erosion;

KmB1: Series K with clay surface soil on very gently sloping (1–3% slope) uplands with slight erosion.

Series L: loamy skeletal, mixed, isohyperthermic Typic Rhodustalf (8.10 ha, 1.53%)

Soils of series L (Fig. 2.9b) are very deep (>150 cm)) and welldrained, and have strong brown to reddish brown, loamy sand or sandy loam surface soils and dark red to dark reddish brown, gravelly sandy clay loam or gravelly sandy clay subsoils. They occur on gently sloping or moderately sloping (3–15% slope) uplands, are developed on granite and are moderately eroded. These soils are mostly cultivated to rainfed *kharif* crops.

The soils are slightly acid (pH 6.0–6.2) in the upper part of the profile and mildly alkaline or moderately alkaline (pH 7.6–8.4) in the lower part. Clay content is 12.5 per cent in the surface soil and ranges from 29.1 to 45.9 per cent in the subsoil. The cation exchange capacity is 7.1 cmol (+) kg^{-1} in the surface soil and 13.9–16.5 cmol (+) kg^{-1} in the subsoil. Organic carbon content (0.37%) is low. The estimated available water capacity is low (50–100 mm).

The following phases of series L were mapped in the watershed.

Lg1bC2St3: Series L with loamy sand surface soil with <15 per cent gravel on gently sloping (3–8% slope) uplands with moderate erosion, 3–15 per cent stones on the surface;

Lg1cD2St3: Series L with sandy loam surface soil with <15 per cent gravel on moderately sloping (8–15% slope) uplands with moderate erosion, 3–15 per cent stones on the surface.

Series M: fine, mixed, isohyperthermic, Typic Haplustalf (11.38 ha, 2.16%)

Soils of series M (Fig. 2.10a) are very deep (>150 cm) and welldrained or moderately well drained, and have strong brown to dark brown, sandy loam surface soils and dark brown to dark reddish brown, sandy loam and sandy clay loam subsoils. They occur on very gently sloping (1–3% slope) uplands, are formed on weathered granite and are slightly eroded. These soils are cultivated to rainfed *kharif* crops and at places to crops irrigated from borewells.

The soils are neutral (pH 7.2) in the surface layer and neutral to moderately alkaline (pH 6.6–8.3) in the subsoil. Clay content is 6.9 per cent in the surface soil and increases (12.9–27.3%) with depth down the profile. The cation exchange capacity is 7.1 cmol (+) kg^{-1} in the surface soil and 7.7–10.6 cmol (+) kg^{-1} in the subsoil. Base saturation is high (100%) in the surface soil and decreases down the profile. Organic carbon content (0.43%) is low. The estimated available water capacity is medium (100–150 mm).

The following phases of series M were mapped in the watershed.

McB1: Series M with sandy loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

MhB1: Series M with sandy clay loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion.

Series N: coarse-loamy, mixed, isohyperthermic, Fluventic Haplustept (30.07 ha, 5.71%)

Soils of series N (Fig. 2.10b) are very deep (>150 cm) and moderately well drained or welldrained, and have reddish brown to dark reddish brown, loamy sand to sandy loam and sandy clay loam surface soils and yellowish red to dark reddish brown and dark red, gravelly sandy loam to sand and sandy loam to sandy clay loam stratified subsoils. They are formed on weathered granite, occur on very gently sloping uplands and fringes of valleys with slopes of 1–3 per cent and are slightly eroded. They are under cultivation to rainfed as well as irrigated crops.

The soils are mildly alkaline (pH 7.5) in the surface and mildly alkaline or moderately alkaline (pH 7.5–8.4) in the subsoil. Clay content is 25.6 per cent in the surface soil and decreases irregularly (3.1–24.6%) down the profile. Cation exchange capacity is 12.3 cmol (+) kg^{-1} and decreases irregularly (2.0–5.9 cmol (+) kg^{-1}) in the subsoil. Base saturation is 57 per cent in the surface soil and ranges from 50 to 60 per cent in the subsoil. Organic carbon content (0.43%) is low and decreases irregularly down the profile. The estimated available water capacity is medium (100–150 mm).

The following phases of series N were mapped in the watershed.

NbB1: Series N with loamy sand surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

NcB1: Series N with sandy loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

NhB1: Series N with sandy clay loam surface soil on very gently sloping (1–3% slope) uplands with slight erosion;

NiB1: Series N with sandy clay surface soil on very gently sloping (1–3% slope) uplands with slight erosion.

Miscellaneous lands

Gullied lands. These are very severely eroded and cut-up lands characterized by the presence of numerous gullies 1–2 m deep and about 1–3 m wide. These lands occur in the southwestern part of the watershed and cover 1.63 ha. Presently, these lands are unsuitable for cultivation and need intensive soil conservation measures to arrest further extension of these gullies.

Rockland and stony land. **These are sheet rock and stony lands of granites exposed in the western part of the watershed and cover considerable area (40.40 ha). The granite sheet rocks are of high quality and are presently being mined for export purposes.**

The physical and chemical properties of the typical pedons of the soil series are given in Table 2.3.

2.2 Current Fertility Status of the Soils

Surface soil samples collected from sites at 80-m intervals in a grid pattern from the entire area of the watershed (Fig. 2.11) were analysed for levels of available macronutrients N, P and K and micronutrients Fe, Zn, Cu and Mn. The data were used to generate status maps for each nutrient. The available-nitrogen status was low in 78 per cent of the area of the watershed (Fig. 2.12). Available phosphorus level was low in 37.9 per cent and medium in 36.89 per cent of the area (Fig. 2.13). Available potassium levels were also mostly medium (46.55%) and low (23.55%) as depicted in Fig. 2.14. More than half the area (51.81%) had soils deficient in available zinc (Fig. 2.15), but the soils were mostly adequate in available iron, manganese and copper.

2.3 Soil Survey Interpretations

The soil and site characteristics of the 85 soil phases (Table 2.4) were used in conjun-ction with the morphological features (Table 2.2) and physical and

chemical properties (Table 2.3) of the soil series for interpretation of the soil units.

2.3.1 Land capability

The soil map units in the watershed were grouped under five land capability classes, nine land capability subclasses and 13 land capability units. The area under each land capability unit, soil map units grouped and the area under each unit are given in Table 2.5; the land capability map is presented in Fig. 2.16. Of the total area of 482.7 ha in the watershed, about 430 ha (81.6%) was suitable for agriculture and about 53 ha (10%) was not suitable for agriculture but well suited to forestry, pasture, agri-horti-silvipastoral system, quarrying, as habitat for wild-life and and for recreation. Of the area suitable for agriculture, about 342 ha (65%) area has good cultivable lands (class II) with minor soil and topography (slope) problems: about 46 ha (8.8%) area has moderately good cultivable lands with moderate problems of soil and erosion, and about 42 ha (8%) area has fairly good cultivable lands with severe problems of erosion, gravelliness, stoniness and moderate slopes.

The 13 land capability units identified in the watershed are briefly described below as regards their soil and land characteristics and soil and water conservation measures to be adopted for sustained production.

Table 2.5 Land capability — Garakahalli microwatershed

Land capability unit	***Soil units***	***Area***	
		ha	%
IIS2	CbB1, Cg1bC1, Dg1bB1, EbB1, FbB1, GbB1, HbB1, Hg1bB1, Hg2bB1, IbC1, KbB1, NbB1,	71.48	13.56
IIS3	DmB1, EmB1, Hg1iC1, ImB1, KmB1	32.74	6.21
IIS9	CcB1, Cg1hB1, Cg2fB1, ChB1, CiC1, Dg1cC1, Eg1iB1, FcB1, FhB1, FiB1, GcB1, Gg1iC1, HcB1, Hg1hB1, Hg1iB1, Hg2iC1, Hhb1, IcB1, IcC1, Ig1hC1, IhB1, IiB1, JhB1, JiB1, KcB1, KcC1, Kg1cB1, Kg1hB1, KhB1, KhC1, KiC1, McB1, MhB1, NcB1, NhB1, NiB1	234.57	44.49
IIS9–VIIIS0	Eg1hB1–R	5.33	1.01
IIIS0	Dg1bB1St3, Eg1cB1St3, Gg1hC1St3, HcB1St3, HmC1St3	10.38	1.97

IIIS8	BcB1, BmB1	7.35	1.39
IIIe1	CcC2, IiC2, ImB2	6.08	1.15
IIIes	Gg2hC2St3, Ig2hc2St3, Lg1bC2St3	14.14	2.68
IIIes2	GbB2, KbC2	7.78	1.48
IVe1	KhD2	6.78	1.29
IVes0	Ag2hD2St4, Eg2cC2St4, Hg1cD2St4, Hg1hD2St4, Hg2cD2St3, Hg2hD2St4, Jg1hD2St3, KhD2St3, Lg1cD2St3	27.43	5.20
IVes–VIIIS0	Gbc2st3–R, Gg2cD2St4–R, Kg1hC2St4–R, Kg2hD2St4–R	13.39	2.54
VIes0	Gg1cE3St4, Gg1hE3St4	3.22	0.61
VIIIS0	Rockland and stony land	40.40	7.66
VIIIe1x	Gullied land	1.63	0.31

Key to land-capability unit limitations

0	Stony or rocky	5	Coarse substrata
1	Erosion hazard/slope	6	Salinity/alkalinity
2	Coarse texture (surface)	7	Stagnation/overflow
3	Fine texture (surface)	8	Effective rooting depth
4	Slowly permeable subsoil	9	Fertility

Lands suitable for agriculture; 430 ha (81.6%)

Land capability unit IIS2; 71.48 ha (13.56%). These are good cultivable lands with minor problem of coarse-textured surface soil. The soils are moderately deep to very deep (75–150+ cm) and have loamy sand and sandy loam surface soils and sandy clay, clay and sandy clay loam subsoils. They occur on very gently sloping and gently sloping (1–5% slope) uplands and are susceptible to sheet and rill erosion. Soil- and water- conservation measures required are contour bunds with open ends or waste weirs, graded bunds and graded or contour border strips. The soil mapping units grouped under this land capability unit are CbB1, Cg1bC1, Dg1bB1, EbB1, FbB1, GbB1, HbB1, Hg1bB1, Hg2bB1, IbC1, KbB1 and NbB1.

Land capability unit IIS3; 32.74 ha (6.21%). These are good cultivable lands with minor problem of heavy-textured surface soil. The soils grouped under this land capability unit are moderately deep to very deep (75–150+ cm), fine textured soils on gently sloping (3–5% slope) uplands. They are susceptible to sheet and rill erosion and need appropriate soil and water conservation measures like contour border strips.

The soil mapping units grouped under this land capability unit are DmB1, EmB1, Hg1iC1, ImB1 and KmB1.

Land capability unit IIS9; 234.57 ha (44.49%)

These are good cultivable lands with minor problems of low fertility and heavy-textured surface soil. The soils grouped under this land capability unit are moderately deep to very deep (75–150+ cm) and have sandy loam, sandy clay loam, sandy clay or clay surface soils and sandy clay or clay and sandy clay loam subsoils. They occur on very gently sloping and gently sloping (1–5% slope) uplands and are susceptible to sheet and rill erosion. Recommended soil and water conservation measures are contour bunds with open ends or waste weirs, graded bunds and graded or contour border strips. All climatically adapted *kharif* crops can be grown.

The soil mapping units grouped under this land capability unit are CcB1, Cg1hB1, Cg2fB1, ChB1, CiC1, Dg1cC1, Eg1iB1, FcB1, FhB1, FiB1, GcB1, Gg1ic1, HcB1, Hg1hB1, Hg1iB1, Hg2iC1, HhB1, IcB1, IcC1, Ig1hC1, IhB1, IiB1, JhB1, JiB1, KcB1, KcC1, Kg1cB1, Kg1hB1, KhB1, KhC1, KiC1, McB1, MhB1, NcB1, NhB1 and NiB1.

Land capability unit IIS9–VIIIS0; 5.33 ha (1.01%). These are good cultivable lands associated with rock outcrops and have the minor problem of low fertility. The soils grouped under this land capability unit are moderately deep (75–100 cm) sandy clay loam soils on very gently sloping (1–3% slope) uplands associated with rock outcrops in complex pattern. They are susceptible to sheet and rill erosion and need soil and water conservation measures like contour bunds with open ends or waste weirs, graded bunds and graded or contour border strips. Low fertility and rockiness are the problems associated with these lands. All climatically adopted *kharif* crops can be grown.

The soil mapping unit under this land capability unit is Eg1hB1–R.

Land capability unit IIIS0; 10.38 ha (1.97%). These are moderately good cultivable lands with problems of stoniness (3–15% stones) on the surface. The soils grouped under this land capability unit are moderately deep or deep (75–150 cm), and have loamy sand, sandy loam or sandy clay surface soils and sandy clay loam, sandy clay or clay subsoils. They occur on very gently sloping and gently sloping (1–5% slope) uplands and have problems of surface stoniness (3–15%), which hinders land preparation and mechanization. They are susceptible to sheet and rill erosion and need soil and water conser-vation measures like contour bunds with open ends or waste weirs, graded bunds and graded or contour border strips. All climatically adapted crops can be grown.

The soil mapping units grouped under this unit are Dg1bB1St3, Eg1cB1St3, Gg1hC1St3, HcB1St3 and HmC1St3.

Land capability unit IIIS8; 7.35 ha (1.39%). These are moderately good cultivable lands with the problem of effective rooting depth. The soils grouped under this land capability unit are moderately shallow (50–75 cm), and have sandy loam or sandy clay loam surface soils and sandy clay or sandy clay loam subsoils. They occur on very gently sloping (1–3% slope) uplands and are very susceptible to sheet and rill erosion. Recommended soil and water conservation measures are contour bunds with open ends or waste weirs, graded bunds and graded or contour border strips. Short-duration crops can be grown.

The soil mapping units grouped under this unit are BcB1 and BmB1.

Land capability unit IIIe1; 6.08 ha (1.15%). These are moderately good cultivable lands with the problem of water erosion and moderate slopes. The soils grouped under this land capability unit are moderately deep and deep (75–150 cm) with sandy loam to sandy clay and clay surface soils and sandy clay and clay subsoils, and occur on gently sloping (3–5% slope) uplands. These soils need intensive soil- and water-conservation measures such as graded bunds and graded border strips. All climatically adapted crops can be grown.

The soil mapping units grouped under this land capability unit are CcC2, IiC2 and ImB2.

Land capability unit IIIes; 14.14 ha (2.68%). These are moderately good cultivable lands with problems of water erosion and stoniness at the surface. The soils grouped under this land capability unit are deep and very deep (100–150 cm), and have loamy sand and sandy clay loam surface soils and sandy clay loam to gravelly sandy clay loam subsoils. They occur on gently sloping (3–5% slope) uplands and have problems of water erosion, gravelliness, and surface stoniness (3–15%) stones). They need intensive soil and water conservation measures like graded bunds and graded border strips. All climatically adapted crops can be grown.

The soil map units grouped under this unit are Gg2hC2St3, Ig2hC2St3 and Lg1bC2St3.

Land capability unit IIIes2; 7.78 ha (1.48%). These are moderately good cultivable lands with problems of water erosion, coarse surface texture (loamy sand) and slopes. The soils grouped under this unit are deep and very deep (100–150+ cm), and have loamy sand, sandy loam or sandy clay loam surface soils and sandy clay loam, sandy clay and gravelly sandy clay subsoils. They occur on gently sloping (3–5% slope) uplands and are susceptible to erosion. They need intensive soil and water conservation measures. Recommended conservation measures are graded bunds and graded border strips. All climatically adapted crops can be grown.

The soil mapping units grouped under this unit are GbB2 and KbC2.

Land capability unit IVe1; 6.78 ha (1.29%). These are fairly good cultivable lands with moderate problems of slope (5–10%) and water erosion. The soils grouped under this land capability unit are very deep (>150 cm), and have sandy clay loam surface soils and sandy clay loam, sandy clay and gravelly sandy clay subsoils. They occur on moderately sloping (5–10% slope) uplands and are susceptible to water erosion, requiring intensive soil and water conservation measures. Recommended conservation measures are graded bunds and graded trenches, and provision of grassed waterways leading to farm ponds. They are marginal lands suitable for occasional growing of short- and medium-duration crops and are better suited to silvipasture, agri-horti-silvipasture and agroforestry.

The soil-mapping unit under this unit is KhD2.

Land capability unit IVes; 27.43 ha (5.20%). These are fairly good cultivable lands with moderate problems of water erosion and stoniness (3–90% stones) on the surface. The soils grouped under this land capability unit are very shallow (<25 cm), moderately deep and deep (75–150 cm), and have sandy loam or sandy clay loam, gravelly and stony surface soils and loamy to clayey subsoils. They occur on moderately sloping (5–10% slope) uplands and are very susceptible to water erosion, requiring intensive soil and water conservation

measures like graded bunds with grassed waterways leading to farm ponds and graded trenches. They are marginal lands fit for occasional short-duration crops but well suited for agri-horti-silvipasture, pasture, silvipasture and agroforestry.

The soil map units grouped under this land capability unit are Ag2hD2St4, Eg2cC2St4, Hg1cD2St4, Hg1hD2St4, Hg2cD2St3, Hg2hD2St4, Jg1hD2St3, KhD2St3 and Lg1cD2St3.

Land capability unit IVes0–VIIIs0; 13.39 ha (2.54%). These are fairly good cultivable lands with moderate problems of water erosion, mode-rate slopes and surface stoniness (15–90% stones) associated with rock outcrops in complex pattern. The soils grouped under this unit are deep and very deep (100–150 cm), and have loamy sand, sandy loam and sandy clay loam, gravelly and stony surface soils and sandy clay loam, sandy clay and gravelly sandy clay subsoils. They occur on gently sloping and moderately sloping (3–10% slope) uplands and are susceptible to water erosion, requiring intensive soil and water conservation measures. Recommended conservation measures are graded bunds with grassed waterways leading to farm ponds and graded trenches. These are marginal lands suitable for occasional short-duration crops but well suited to pasture, silvipasture and agri-horti-silvipasture and agroforestry.

The soil mapping units grouped under this unit are Gbc2St3–R, Gg2cD2St4–R, Kg1hD2St4–R and Kg2hC2St4–R.

Lands not suitable for agriculture

Land capability unit VIeS0; 3.22 ha (0.61%. These lands are not suitable for agriculture because of slope (10–15%), severe erosion and surface stoniness (15–90% stones). The soils grouped under this unit are deep (100–150 cm), and have sandy loam or sandy clay loam, gravelly and highly stony surface soils and sandy clay loam subsoils. They occur on moderately steeply sloping (10–15% slope) uplands and are susceptible to water erosion, requiring intensive soil and water conservation measures. Recommended conservation measures are graded bunds with grassed waterways leading to farm ponds and graded

trenches. These lands are suitable for forestry, agro-forestry, pasture and silvipasture.

The soil mapping units grouped under this unit are Gg1cE3St4 and Gg1hE3St4.
Land capability unit VIIIS0; 40.40 ha (7.66%). These are lands characterized by presence of high-grade granite sheet rock. Good for quarrying and mining for use as building material.

The mapping units grouped under this unit are rockland and stony lands.

Land capability unit VIIIe1; 1.63 ha (0.31%). Lands under this unit are miscellaneous lands characterized by presence of a large number of gullies giving the appearance of broken and cut-up land. They need stabilization of gullies by adoption of appropriate gully-plugging methods and growing of grasses on gully sides and bottom.

2.3.2 Land irrigability

The soil units of the watershed were grouped under four land irrigability classes and seven land irrigability subclasses. The soil map units grouped and the area under each irrigability subclass are given in Table 2.6; the land irrigability map is presented in Fig. 2.17. Of the total area of the watershed, about 428 ha (81.2%) of land was suitable for irrigation and about 55 ha (10.4%) was not suitable for irrigation. Of the area suitable for irrigation, about 321.4 ha (61%) consisted of good irrigable lands (class 2) with moderate limitations, about 41.9 ha (8%) moderately good irrigable lands (class 3) with severe limitations and about 64.6 ha (12.2%) lands marginally suitable for irrigation with very severe limitations.

The nine land irrigability map units identified in the watershed area are described below.

Land irrigability subclass 2s; 28815 ha (54.66%). These are good irrigable lands with moderate limitations of soil (coarse and heavy texture), less than ideal soil

depth and permeability, and medium available water capacity for sustained use under irrigation. The soils grouped under this unit are moderately shallow to deep (75–150 cm) and have coarse or heavy surface soils and sandy clay loam, sandy clay and clay subsoils. They occur on very gently sloping (1–3% slope) uplands.

The soil mapping units grouped under this land irrigability subclass are BcB1, BmB1, Bmb1, CbB1, CcB1, ChB1, DmB1, EbB1, EmB1, FbB1, FcB1, FhB1, FiB1, GbB1, GbB2, GcB1, HbB1, HcB1, HhB1, IcB1, IhB1, IiB1, ImB1, ImB2, JhB1, JiB1, KbB1, KcB1, KhB1, KmB1, McB1, MhB1, NbB1, NcB1, NhB1 and NiBi.

Land irrigability subclass 2st; 29.94 ha (5.68%). These are good irrigable lands with moderate limitations for sustained use under irrigation. They have moderate limitations of soil (coarse and heavy textures), somewhat unfavourable topography (3–5% slopes), less than ideal soil depth and permeability, and low or medium available water capacity. They are susceptible to erosion. The soils grouped under this unit are moderately deep to very deep (75–150+ cm), and have loamy sand, sandy loam, sandy clay loam or sandy clay surface soils and sandy clay loam, sandy clay and clay subsoils. They occur on gently sloping uplands (3–5% slopes).

The soil mapping units grouped under this land irrigability subclass are CcC2, Cic1, Ibc1, IcC1, IiC2, KbC2, KcC1, KhC1 and KiC1.

Table 2.6 Land irrigability – Garakahalli microwatershed

Land irrigability subclass	***Soil units***	***Area***	
		ha	%
2s	BcB1, BmB1, CbB1, CcB1, ChB1, DmB1, EbB1, EmB1, FbB1, FcB1, FhB1, FiB1, GbB1, GbB2, GcB1, HbB1, HcB1, HhB1, IcB1, IhB1, IiB1, ImB1, ImB2, JhB1, JiB1, KbB1, KcB1, KhB1, KmB1, McB1, MhB1, NbB1, NcB1, NhB1, NiB1	288.15	54.66
2st	CcC2, Cic1, IbC1, IcC1, IiC2, KbC2, KcC1, KhC1, KiC1	29.94	5.68
2st–6st	Eg1hB1–R	5.33	1.01
3s	Cg1hB1, Cg2fB1, Dg1bB1, Eg1iB1, Hg1bB1, Hg1hB1, Hg1iB1, Hg2bB1, Kg1cB1, Kg1hB1	28.95	5.49
3st	Cg1bc1, Dg1cC1, Gg1iC1, Hg1iC1, Hg2iC1, Ig1hC1	12.95	2.46
4s	Dg1bB1st3, Eg1cB1St3, Eg2cC2st4, Gg1hC1st3, Gg2hC2st3, HcB1St3, HmC1St3, Ig2hC2St3, Lg1bC2St3	26.57	5.04
4st	Hg1cD2St4, Hg1hD2St4, Hg2cD2St3, Hg2hD2St4, Jg1hD2St3, KhD2, KhD2St3, Lg1cD2St3	30.09	5.71
4st–6st	GbC2St3–R, Gg2cD2St4–R, Kg1hC2St4–R, Kg2hD2St4–R	13.39	2.54
6st	Ag2hD2St4, Gg1cE3St4, Gg1hE3St4, rockland and stony land, gullied land	47.33	8.98

Key to limitations in irrigability subclasses:

2 Lands with moderate limitations 3 Lands with severe limitation

4 Lands with very severe limitation 6 Land not suitable for irrigation

R Rockland s Soil limitation

t Topographic limitation

Land irrigability subclass 2st–6st; 5.33 ha (1.01%). These are good irrigable lands with moderate limitations for sustained use under irrigation associated with lands not suitable for irrigation because of rock outcrops in complex pattern. They have moderate limitations of coarse fragments (15–35% gravel) and rock outcrops that hinder land levelling and land preparation. The soils grouped under this unit are moderately deep (75–100 cm), and have sandy clay loam surface

soils and sandy clay loam or sandy loam subsoils. The soil unit under this land irrigability subclass is Eg1hB1–R.

Land irrigability subclass 3s; 28.95 ha (5.49%). These are moderately good irrigable lands with severe limitations for sustained use under irrigation. They have severe limitations of coarse fragments (15–35+% gravel), coarse or heavy textures, unfavourable soil depth, permeability and available water capacity. The soils grouped under this subclass are moderately deep or deep (75–150 cm), and have loamy sand, sandy loam, sandy clay loam, sandy clay or clay surface soils and sandy clay loam, sandy clay and clay subsoils. They occur on very gently sloping (1–3% slope) uplands.

The soil map units grouped under this land irrigability subclass are Cg1hB1, Cg2fB1, Dg1bB1, Eg1iB1, Hg1bB1, HgihB1, Hg2bB1, Hg1iB1, Kg1cB1 and Kg1hB1.

Land irrigability subclass 3st; 12.95 ha (2.46%). These are moderately good irrigable lands with severe limitations for sustained use under irrigation. They have severe limitations of either soil or topography. Limitations include singly or in combination the effects of coarse fragments (15–60% gravel), unfavourable soil depth, texture, permeability, available water capacity and gentle slopes. The soils grouped under this unit are moderately deep to very deep, and have loamy sand, sandy loam, sandy clay loam or sandy clay surface soils and sandy clay loam, sandy clay and clay subsoils. They occur on gently sloping (3–5% slope) uplands.

The soil mapping units grouped under this land irrigability subclass are Cg1bC1, Dg1cC1, Gg1iC1, Hg1iC1, Hg2iC1 and Ig1hC1.

Land irrigability subclass 4s; 26.57 ha (5.04%). These lands are marginal for sustained use under irrigation because of very severe limitations of either soil or topography. Limitations include stoniness/gravelliness or coarse and heavy textures, permeability, available water capacity and slope. The soils grouped under this unit are moderately deep to very deep (75–150+ cm), and have loamy sand, sandy loam, sandy clay loam, sandy clay or clay surface soils and sandy

clay loam, sandy clay and clay subsoils. They occur on gently sloping (3–5% slope) uplands and are slightly or moderately eroded.

The soil mapping units grouped under this land irrigability subclass are Dg1bB1St3, Eg1cB1St3, Eg2cC2St4, Gh1hC1St3, Gg2hC2St3, HcB1St3, HmC1St3, Ig2hC2St3 and Lg1bC2St3.

Land irrigability subclass 4st; 30.09 ha (5.17%). These are marginal lands for sustained use under irrigation due to very severe limitations of either soil or topography. Limitations due to soil are presence of high percentage of stones (3–90%) on the surface, gravelliness and moderate slopes. The soils grouped under this unit are deep or very deep (100–150+ cm), and have sandy loam or sandy clay loam surface soils and clay to loam and gravelly clay to gravelly loam subsoils. They occur on moderately sloping (5–10% slope) uplands with moderate erosion.

The soil mapping units grouped under this land irrigability subclass are Hg1cD2St4, Hg1hD2St4, Hg2cD2St3, Hg2hD2St4, Jg1hD2St3, KhD2, KhD2St3 and Lg1cD2St3.

Land irrigability subclass 4st–6st; 13.39 ha (2.54%). These are marginal lands for sustained use under irrigation because of very severe limitations associated in complex pattern with lands not suitable for sustained use under irrigation. The very severe limitations are of soil (stoniness and gravelliness), topography or associated rock outcrops.

The soil mapping units grouped under this land irrigability subclass are GbC2St3–R, Gg2cD2St4–R, Kg1hC2St4–R and Kg2hD2St4–R.

Land irrigability subclass 6st; 47.33 ha (8.98%). These are lands not suitable for sustained use under irrigation. The lands of this subclass have very severe limitations of either soil or topography or eroded gullied lands and sheet rock areas. Delivery of irrigation water is not feasible due to steep slopes.

The soil mapping units grouped under this land irrigability subclass are Ag2hD2St4, Gg1cE3St4, Gg1hE3St4, gullied land, stony land and rockland.

2.3.3 Problem and potential soils

Soil depth. The soil map units of the watershed were grouped into eight depth-class associations. The soil units grouped under each class are given in Table 2.7 and the soil depth map in Fig. 2.18. About 49.6 ha (9.4%) of area in the watershed has very deep (>150 cm) soils, about 300 ha (57%) has deep (100–150 cm) soils and about 81 ha (15.4%) has moderately deep (75–100 cm) soils. These constitute about 430 ha (81.8%) and have high potential for growing all climatically adapted agricultural and horticultural crops. About 2 ha (0.4%) area has very shallow (10–25 cm depth) soils and about 7.3 ha (1.4%) has moderately shallow (50–75 cm depth) soils. These shallow soils cover about 9 ha (2%) area where shallow rooted crops can be grown occasionally and are well suited for pasture, agroforestry or silvipasture. About 42 ha (8%) area in the watershed has rock land, stony land and gullied land.

Table 2.7 Soil depth — Garakahalli microwatershed

Soil depth class	Soil units	*Area*	
		ha	%
10–25 cm	Ag2hD2St4	2.08	0.39
25–50 cm	BcB1, BmB1	7.35	1.39
51–75 cm	CbB1, CcB1, CcC2, Cg1bC1, Cg1hB1, Cg2fB1, ChB1, CiC1, Dg1bB1, Dg1bB1St3, Dg1cC1, DmB1, EbB1, Eg1cB1St3, Eg1hB1–R, Eg1iB1, Eg2cC2 St4, EmB1	81.09	15.38

101–150 cm	FbB1, FcB1, FhB1, FiB1, GbB1, GbB2, GbC2St3–R, GcB1, Gg1cE3St4, Gg1hC1St3, Gg1hE3St4, Gg1iC1, Gg2cD2St4–R, Gg2hC2St3, HbB1, HcB1, HcB1St3, Hg1bB1, Hg1cD2St4, Hg1hB1, Hg1hD2St4, Hg1iB1, Hg1iC1, Hg2bB1, Hg2cD2St3, Hg2hD2St4, Hg2iC1, HhB1, HmC1St3, Ibc1, IcB1, IcC1, Ig1hC1, Ig2hC2St3, IhB1, IiB1, IiC2, ImB1, ImB2, Jg1hD2St3, JhB1, JiB1, KbB1, KbC2, KcB1, KcC1, Kg1cB1, Kg1hB1, Kg1hC2St4–R, Kg2hD2St4–R, KhB1, KhC1, KhD2, KhD2St3, KiC1, KmB1	300.60	57.02
>150 cm	Lg1bC2St3, Lg1cD2 St3, McB1, MhB1, NbB1, NcB1, NhB1, NiB1	49.55	9.40
Miscellaneous lands	Rockland and stony land, gullied land	42.03	7.97

Surface soil texture. The soil map units of the watershed were grouped into 10 classes of surface soil texture. The soil units grouped under each class and area are given in Table 2.8 and the corresponding map in Fig. 2.19. About 265 ha (50%) area has loamy soils and about 86 ha (16%) clayey soils. These together constitute about 351 ha (66%) and have high potential for nutrients and available water-holding capacity and are ideal for growing most agricultural and horticultural crops. About 90 ha (17%) has sandy soils that have low nutrient reserves and low available water capacity and as such their use for agricultural and horticultural crops is restricted. About 42 ha (8%) has miscellaneous lands comprising rocky and stony lands and gullied lands.

Table 2.8 Surface soil texture — Garakahalli microwatershed

Surface soil texture class	**Soil units**	**Area**	
		ha	%
Loamy sand (ls)	**CbB1, Cg1bC1, Dg1bB1, Dg1bB1St3, EbB1, FbB1, GbB1, GbB2, GbC2St3–R, HbB1, Hg1bB1, Hg2bB1, IbC1, KbB1, KbC2, Lg1bc2St3, NbB1**	89.81	17.03
Sandy loam (sl)	BcB1, CcB1, CcC2, Dg1cC1, Eg1cB1St3, Eg2cC2 St4, FcB1, GcB1, Gg1cE3St4, Gg2cD2St4–R, HcB1, HcB1St3, Hg1cD2St4, Hg2D2St3, IcB1, IcC1, KcB1, KcC1, Kg1cB1, Lg1cD2St3, McB1, NcB1	121.59	23.06
Sandy clay loam (scl)	**Ag2hD2St4, Cg1hB1, ChB1, Eg1hB1–R, FhB1, Gg1hC1St3, Gg2hC2St3, Gg1hE3St4, Hg1hB1, Hg1hD2St4, Hg2hD2St4, HhB1, Ig1hC1, Ig2hC2St3, IhB1, Jg1hD2St3, JhB1, Kg1hB1, Kg1hC2St4–R, Kg2hD2St4–R, KhB1, KhC1, KhD2, KhD2St3, MhB1, NhB1**	141.78	26.89
Clay loam (cl)	**Cg2fB1**	1.31	0.25
Sandy clay (scl)	**Cic1, Eg1iB1, FiB1, Gg1ic1, Hg1iB1, Hg1iC1, Hg2iC1, IiB1, IiC2, JiB1, KiC1, NiB1**	49.26	9.34
Clay (c)	**BmB1, DmB1, EmB1, HmC1St3, ImB1, ImB2, KmB1**	36.92	7.00
Miscellaneous land	**Rockland and stony land, gullied land**	42.03	7.97

Soil gravelliness. The soil map units of the watershed were grouped into four gravelliness classes. The soil units grouped under each class are given in Table 2.9 and the corresponding map in Fig. 2.20. About 29 ha (5.5%) area had strongly gravelly (35–60%) soils and about 71 ha (13.5%) area had moderately gravelly (15–35%) soils. An area of about 42 ha (8%) had dominantly rocky and stony lands. These together constituted about 142 ha (26.5%) that had problems with regard to seedbed preparation, seedling emergence and low available water capacity. About 340 ha (65%) had non-gravelly (<15% gravel) soils with high potential.

Stoniness. The soils of the watershed were grouped into four stoniness classes. The soil units grouped under each class are given in Table 2.10 and the

corresponding map in Fig. 2.21. About 40.5 ha (7.7%) of area had soils that were moderately stony (3–15% stones) on the surface, about 33.3 ha (6.3%) had strongly stony (15–90% stones) soils and about 42 ha (8%) had predominantly stony lands and rocklands. These together constitute about 116 ha (22%) with impedance to farm management activities such as ploughing, land levelling, sowing, seedbed preparation, interculture operations, etc. An area of about 367 ha (70%) had no stones or very few stones (0–3%) on the surface and did not have much problems in management.

Soil available water capacity. The soil map units of the watershed were grouped under four available water capacity (AWC) classes. The soil units under each AWC class are given in Table 2.11 and the map in Fig. 2.22. About 56.6 ha (10.7%) of area had soils with low AWC (50–100 mm) and 2 ha with very low AWC (<50 mm). Only short-duration *kharif* crops could be grown on these lands. About 382 ha (72.5%) area had soils with medium AWC (100–150 mm) on which medium-duration crops could be grown. About 42 ha (8%) had stony, rock and gullied lands.

Slope. The soil map units of watershed were grouped under five slope classes. The soil units under each class and are given in Table 2.12 and the slope map in Fig. 2.23. About 3.2 ha (0.6%) had strongly sloping (10–15% slope) lands and about 37 ha (7%) had moderately sloping (5–10% slope) lands. These together constituted about 40 ha (8%) prone to water erosion and as such would need intensive soil- and water-conservation measures for sustained production. About 71 ha (13.5%) area had gentle slopes (3–5% slopes) and was prone to water erosion. About 330 ha (62.5%) had very gently sloping lands on which all climatically adapted crops could be grown. About 42 ha (8%) was miscellaneous land comprising rocky, stony and gullied lands.

Table 2.9 Soil gravelliness — Garakahalli microwatershed

Soil gravelliness class (gravel %)	**Soil units**	**Area**	
		ha	%
Non-gravelly	**BcB1, BmB1, CbB1, CcB1, CcC2, ChB1, CiC1, DmB1, EbB1, EmB1, FbB1, FcB1, FhB1, FiB1, GbB1, GbB2, GbC2St3–R, GcB1, HbB1, HcB1, HhB1, HcB1St3, HhB1, Hmc1St3, IhB1, IcB1, IcC1, IiB1, IhB1, IiB1, IiC2, ImB1, ImB2, JhB1, JiB1, KbB1, KbC2, KcB1, KcC1, KhB1, KhC1, KhD2, KhD2St3, KiC1, KmB1, McB1, MhB1, NbB1, NcB1, NhB1, NiB1**	340.39	64.56
g1 (<15)	Cg1bC1, Cg1hB1, Dg1bB1, Dg1bB1St3, Dg1cC1, Eg1cB1St3, Eg1hB1–R, Eg1iB1, Gg1icE3St4, Gg1hC1St3, Gg1hE3St4, Hg1bB1, Hg1cD2St4. Hg1hB1, Hg1hD2St4, Hg1iB1, Hg1iC1, Ig1hC1 Jg1hD2St3, Kg1Cb1, Kg1hB1, Kg1hC2St4–R, Lg1bC2St3, Lg1cD2St3	71.18	13.50
g2 (15–35)	Ag2hD2St4, Cg2fB1, Eg2cC2St4, Gg2hC2St3, Gg2cD2St4–R, Hg2bB1, Hg2cD2St3, Hg2cD2St4, Hg2iC1, Ig2hC2St3, Kg2hD2St4–R	29.09	5.52
Miscellaneous land	**Rockland and stony land, gullied land**	42.03	7.97

Table 2.10 Surface stoniness — Garakahalli microwatershed

Stoniness class (% stones)	**Soil units**	**Area**	
		ha	%
Non-stony to slightly stony (0–3)	**BcB1, BmB1, CbB1, CcB1, CcC2, Cg1bc1, Cg1hB1, Cg2fB1, ChB1, CiC1, Dg1Bb1, Dg1cC1, DmB1, EbB1, Eg1iB1, EmB1, FbB1, FcB1, FhB1, FiB1, GbB1, GbB2, GcB1, Gg1iC1, HbB1, HcB1, Hg1bB1, Hg1hB1, Hg1iB1, Hg1iC1, Hg2bB1, Hg2iC1, HhB1, IbC1, IcB1, IcC1, Ig1hc1, IhB1, IiB1, IiC2, ImB1, ImB2, JhB1, JiB1, KbB1, KbC2, KcB1, KcC1, Kg1cB1, Kg1hB1, KhB1, KhC1, KhD2, KiC1, KmB1, McB1, MhB1, NbB1, NcB1, NhB1, NiB1**	366.77	69.57
Moderately stony (3–15)	Dg1bB1St3, Eg1cB1St3, GbC2St3–R, Gg1hC1St3, Gg2h2St3, HcB1St3, Hg2cD2St3, Hmc1 St3, Ig2hC2St3, Jg1hD2St3, KhD2St3, Lg1bC2St3, Lg1cD2St3	40.48	7.68
Strongly stony (15–90)	Ag2hD2St4, Eg1hB1–R, Eg2cC2St4, Gg1cE3St4, Gg1hE3st4, Gg2cD2St4–R, Hg1cD2St4. Hg1hD2St4, Hg2hD2St4, Kg1hC2St4–R, Kg2hD2St4–R	33.41	6.34
Miscellaneous land	**Rockland and stony land, gullied land**	42.03	7.97

Table 2.11 Soil available water capacity — Garakahalli microwatershed

Available water capacity class	**Soil units**	**Area**	
		ha	%
Very low (<50 mm)	**Ag2hD2St4**	2.08	0.39
Low (50–100 mm)	HbB1, HcB1, HcB1St3, Hg1bB1, Hg1cD2St4, Hg1hB1, Hg1hD2St4, Hg1iB1, Hg1iC1, Hg2bB1, Hg2cD2St3, Hg2hD2St4, Hg2iC1, HhB1, HmC1St3, Lg1bC2St3, Lg1cD2St3	56.70	10.75
Medium (100–150 mm)	BcB1, BmB1, CbB1, CcB1, CcC2, Cg1bc1, Cg1hB1, Cg2fB1, ChB1, CiC1, Dg1bB1, Dg1bB1St3, Dg1cC1, DmB1, EbB1, Eg1cB1St3, Eg1hB1–R, Eg1iB1, Eg2cC2St4, EmB1, FbB1, FcB1, FhB1, FiB1, GbB1, GbB2, GbC2St3–R, GcB1, Gg1cE3St4, Gg1hC1St3, Gg1hE3St4, Gg1ic1, Gg2cD2St4–R, Gg2hC2St3. IbC1, IcB1, IcC1, Ig1hC1, Ig2hC2St3, IhB1. IiB1, IiC2, ImB1, ImB2, Jg1hD2St3, JhB1, JiB1, KbB1, KbC2, KcB1, KcC1, Kg1cB1, Kg1hB1, Kg1hC2St4–R, Kg2hD2St4–R, KhB1, KhC1, KhD2, KhD2St3, KiC1, KmB1, McB1, MhB1, NbB1, NcB1, NhB1, NiB1	381.89	72.44
Miscellaneous land	**Rockland and stony land, gullied land**	42.03	7.97

Table 2.12 Soil slope — Garakahalli microwatershed

Soil slope class	Soil units	Area	
		ha	%
B (1–3%)	BcB1, BmB1, CbB1, CcB1, Cg1hB1, Cg2hB1, Chb1, Dg1Bb1,Dg1bB1St3, DmB1, EbB1, Eg1cB1St3, Eg1sB1–R, Eg1iB1, EmB1, FbB1, FcB1, FhB1, FiB1, GbB1, GbB2, GcB1, HbB1, HcB1, HcB1St3, Hg1bB1, Hg1hB1, Hg1iB1, Hg2bB1, Hhb1, IcB1, IhB1, IiB1, ImB1, ImB2, JhB1, JiB1, KbB1, KcB1, Kg1cB1, Kg1hB1, KhB1, KmB1, McB1, MhB1, NbB1, NcB1, NhB1, NiB1	329.44	62.49

C (3–5%)	CcC2, Cg1bC1, CiC1, Dg1cC1, Eg2cC2St4, GbC2St3–R, Gg1hC1St3, Gg1iC1, Gg2hC2St3, Hg1iC1, Hg2iC1, HmC1St3, IbC1, IcC1, Ig1hC1, Ig2hC2St3, IiC2, KbC2, KcC1, Kg1hC2St4–R, KhC1, KiC1, Lg1bC2St3	70.94	13.46
D (5–10%)	Ag2hD2St4, Gg2cD2St4–R, Hg1cD2St4, Hg1hD2St4, Hg2hd2St4, Jg1 h D2 St3, Kg2hD2St4–R, KhD2, KhD2St3, Lg1cD2St3	37.08	7.03
E (10–15%)	Gg1cE3St4, Gg1hE3St4	3.22	0.61
Miscellaneous lands	Rockland and stony land, gullied land	42.03	7.97

Soil erosion. Based on the intensity of erosion, the soil map units of the watershed were grouped under five erosion classes. The soil units under each class are given in Table 2.13 and the map in Fig. 2.24. About 3.2 ha (0.6%) had severe erosion (soil loss 15–40 t ha^{-1} y^{-1}) and about 1.6 ha area very severe erosion (soil loss >40 t ha^{-1} y^{-1}) in the form of gullied land. These two areas (about 5 ha) need intensive soil- and water-conservation measures. About 76 ha (14%) had moderately eroded (soil loss 5–15 t ha^{-1} y^{-1}) soils with need for appropriate soil- and water-conservation measures. A large area of about 362 ha (69%) had no erosion or slight erosion (soil loss <5 t ha^{-1} y^{-1}) and with need for just simple soil- and water-conservation measures like contour bunding, contour ploughing, etc.

Table 2.13 Soil erosion status — Garakahalli microwatershed

Soil erosion class	**Soil units**	**Area**	
		ha	%
Slight	**BcB1, BmB1, CbB1, CcB1, Cg1bC1, Cg1hB1, ChB1, CiC1, Dg1bB1, Dg1bB1St3, Dg1cC1, DmB1, EbB1, Eg1cB1St3, Eg1hB1–R, Eg1iB1, EmB1, FbB1, FcB1, FhB1, FiB1, GbB1, GcB1, GgihC1St3, Gg1iC1, HbB1, HcB1, HcB1St3, Hg1bB1, Hg1hB1, Hg1iB1, Hg1iC1, Hg2bB1, Hg2iC1, HhB1, HmC1St3, IbC1, IcB1, IcC1, IgihC1, IhB1, IiB1, ImB1, JhB1, JiB1, KbB1, KcB1, KcC1, Kg1cB1, Kg1hB1, KhB1, KhC1, KiC1, KmB1, McB1, MhB1, NbB1, NcB1, NhB1, NiB1**	361.85	68.63

Moderate	Ag2hD2St4, CcC2, Eg2cC2St4, GbB2, GbC2St3–R, Gg2cD2St4–R, Gg2hC2St3, Hg1Cd2St4. Hg1hD2St4, Hg2C D2St3, Hg2hD2St4, IiC2, ImB2, Jg1hD2St3, KbC2, Kg1hC2St4–R, Kg2hD2St4–R, KhD2, KhD2St3, Lg1bC2St3, Lg1cD2St3	75.60	14.34
Severe	Gg1cE3St4,. Gg1hE3St4	3.22	0.61
Miscellaneous lands	**Rockland and stony land, gullied land**	42.03	7.97

2.3.4 Fertility capability

The soil map units in the watershed were grouped into 21 fertility capability units. The area under each unit is presented in Table 2.14 and the corresponding map in Fig. 2.25. Ten soil series had sandy surface soil phases, 14 series had loamy surface soil phases and 11 soil series had clayey surface soil phases. Of the 14 soil series, 6 had >35 per cent gravel in the surface layer, 8 had 15–35 per cent gravel and 4 had no gravel in the surface soil. As for gravel in the subsoil, 4 soil series had >35 per cent, 8 had 15–35 per cent gravel and 2 had no gravel in the subsoil. One soil series had a root-restricting hard rock layer within 50 cm from the surface.

Among the fertility constraints, Al-toxicity was observed in only one series, low ability to retain cationic plant nutrients in 10 series, high P-fixation by iron in 11 series and low K reserve in 11 series. Moisture limitation and nitrogen deficiency were observed in all the soil series.

The fertility capability units identified in the watershed are briefly described below.

SLde: Soils that are sandy in the surface layer and loamy in subsoil layers and have moisture limitation so that seed germination problems may be experienced, low ability to retain nutrients, high rate of infiltration and low water holding capacity in the surface soil.

SC′dk: Soils that are sandy in the surface layer and clayey with 15–35 per cent gravel in subsoil layers and have moisture limitation so that seed

germination problems may be experienced, low K reserve, high rate of infiltration and low water holding capacity in the surface soil and low infiltration rates and medium water-holding capacity in the subsoil, are susceptible to severe soil degradation from erosion exposing undesirable clayey subsoil; high priority to be accorded to erosion control.

Table 2.14 Fertility capability — Garakahalli microwatershed

Fertility capability unit	**Soil units**	**Area**	
		ha	%
SLde	EbB1, GbB1, GbB2, GbC2St3–R, Lg1bC2St3, NbB1	21.37	4.05
SC′dk	**CbB1, Cg1bC1, Dg1bB1, Dg1bB1St3**	21.96	4.16
SC″dek	**FbB1, HbB1, Hg1bB1, Hg2bB1, IbC1**	21.25	4.03
SCdeak	**KbB1, KbC2**	25.23	4.78
Ld	**NcB1, NhB1**	14.71	2.79
Ldk	**Eg1cB1St3, Eg1hB1–R, Gg2cD2St4–R**	9.34	1.77
Lde	**Eg2cC2St4, GcB1, Gg1cE3St4, Gg1hC1St3, Gg1hE3St4, Gg2hC2St3**	19.04	3.61
LCd	**Jg1hD2St3, JhB1**	8.84	1.68
LCde	**IcB1, IcC1, Ig1hC1, Ig2hC2St3, IhB1**	16.34	3.10
LC′dk	**BcB1, CcB1, CcC2, Cg1hB1, Cg2fB1, ChB1, Dg1cC1**	34.10	6.47
LCdek	**FcB1, FhB1, McB1, MhB1**	28.84	5.47
LC″dek	**HcB1, HcB1St3, Hg1cD2St4, Hg1hB1, Hg1hD2St4, HhB1,**	22.66	4.30
L′C″dek	**Hg2cD2St3, Hg2hD2St4, Kg2hD2St4–R, Lg1cD2St3**	11.56	2.19
LCdeak	**KcB1, KcC1, Kg1cB1, Kg1hB1, Kg1hC2St4–R, KhB1, KhC1, KhD2, Kg1CB1, KhD2St3**	97.18	18.43
LRd	**Ag2hD2St4**	2.08	0.39
Cdei	**Gg1iC1, IiB1, ImB1, IiC2, ImB2, JiB1,**	13.68	2.60
Cdeaik	**KiC1, KmB1**	21.08	4.00
CC′dik	**BMb1, DMb1**	7.26	1.38
CC″deik	**FiB1, Hg1iB1, Hg1iC1**	17.53	3.33
C′C″deik	**Hg2iC1, HmC1St3**	4.46	0.85
CL′dik	**CiC1, Eg1iB1, EmB1, NiB1**	22.17	4.21

SC″dek: Soils that are sandy in the surface layer and clayey with >35 per cent gravel in subsoil layers and have moisture limitation so that and seed germination problems may be experienced, low ability to retain nutrients, low K reserve, high rate of infiltration and low water-holding capacity in the surface soil and low infiltration rates and medium water-holding capacity in the subsoil, and are susceptible to severe soil degradation from erosion exposing undesirable hard compact clayey subsoil; high priority is to be given for erosion control measures.

SCdeak: Soils that are sandy in the surface layer and clayey in subsoil layers, and have moisture limitation so that and seed germination problems may be experienced, low ability to retain nutrients, have low K reserve; high rate of infiltration and low water-holding capacity in surface soils and low infiltration rates and medium water holding capacity in subsoil; these soils are susceptible to severe soil degradation from erosion exposing undesirable hard compact clayey subsoil; plants sensitive to A1-toxicity will be affected unless lime is applied, Mn-toxicity may occur on some of these soils; high priority is to be accorded to erosion control.

Ld: Soils that are loamy in surface and subsurface layers and have moisture limitation so that seed germination problems are experienced when monsoon rains are erratic; no major fertility constraints except nitrogen deficiency; medium water holding capacity and medium infiltration capacity.

Ldk: Soils that are loamy in surface and subsurface layers and have moisture limitation so that seed germination problems may be experienced when monsoon rains are erratic, low K reserve, medium water-holding capacity and medium infiltration capacity.

Lde: Soils that are loamy throughout, and have moisture limitation and seed germination problem is often experienced when monsoon rains are erratic and low ability to retain plant nutrients mainly K, Ca and Mg, medium water-holding capacity and medium infiltration capacity; heavy application of these and nitrogen fertilizer should be split.

LCd: Soils that are loamy in surface layer and clayey in subsoil layers and have moisture limita-tions so that seed germination may be experienced when monsoon rains are erratic, medium water-holding capacity and medium infiltration capacity; these soils are susceptible to severe soil degradation from erosion exposing undesirable hard compact clayey subsoil; high priority to be accorded to erosion control; no major fertility constraints except nitrogen deficiency.

LCde: Soils that are loamy in surface layer and clayey in subsoil layers and have moisture limitation and low ability to retain plant nutrients mainly K, Ca and Mg; heavy application of these and nitrogen fertilizer should be split; seed germination problem is often experienced when monsoon rains are erratic; medium water-holding capacity in surface soil and high water-holding capacity in subsoil. Medium infiltration rate in surface layer and low infiltration in subsoil layers; these soils are susceptible to severe soil degradation from erosion exposing hard compact clayey subsoil; high priority to be accorded to erosion control.

LC′dk: Soils that are loamy in surface layer and clayey with 15–35 per cent gravel in subsoil layers, and have moisture limitation and attendant seed germination problem when monsoon rains are erratic, low K reserve, medium water-holding capacity and infiltration rate in surface soil, medium water-holding capacity and low infiltration rate in subsoil layers; these soils are susceptible to severe soil degradation from erosion exposing compact clayey subsoil; high priority to be accorded to erosion control.

LCdek: Soils that are loamy in the surface layer and clayey in subsoil layers and have moisture limitation with seed germination problem when monsoon rains are erratic, low K reserve, low ability to retain plant nutrients mainly K, Ca and Mg; application of these and N fertilizers should be split; these soils have medium water-holding and medium infilt-ration capacity in the surface soil and medium water-holding and low infiltration capacity in subsoil layers; these soils are susceptible to severe soil degradation from erosion exposing hard compact clayey subsoil; high priority is to be accorded to erosion control.

LC″dek: Soils that are loamy in the surface layer and clayey with >35 per cent gravel in subsoil layers and have moisture limitation with seed germination problem when monsoon rains are erratic, low K reserve, low ability to retain plant nutrients mainly K, Ca and Mg; these and N fertilizers are to be applied in split doses; these soils have medium water-holding capacity and infiltration rate in the surface soil and medium water holding capacity and low infiltration rate in subsoil layers; these soils are susceptible to severe soil degradation from erosion exposing hard compact clayey subsoil; needs erosion control measures on priority basis.

L′C″dek: Soils that are loamy in the surface layer with 15–35 per cent gravel and clayey with >35 per cent gravel in subsoil layers and have moisture limitation with seed germination problem when monsoon rains are erratic, low K reserve, low ability to retain plant nutrients mainly K, Ca and Mg; application of these and N fertilizers should be in split doses; these soils have medium water-holding capacity and medium infiltration rate in surface soil and medium water-holding capacity and low infiltration rate in subsoil layers; they are susceptible to severe soil degradation from erosion exposing hard compact clayey subsoil; high priority is to be accorded to erosion control.

LCdeak: Soils that are loamy in surface layer and clayey in subsoil layers and have moisture limitation with seed germination problem when monsoon rains are erratic. They have low K reserve and low ability to retain plant nutrients mainly K, Ca and Mg; application of these and N fertilizers should be in split doses. Liming is required to obviate Al-toxicity; Mn-toxicity may also occur on some of these soils. These soils have medium water-holding capacity and medium infiltration rate in surface soil and medium water-holding capacity and low infiltration rate in subsoil layers; they are susceptible to severe soil degradation from erosion exposing hard compact clayey subsoil; high priority to be accorded to erosion control.

LRd: Loamy soils underlain by hard rock (granite) with severe moisture limitation due to inadequate soil depth.

Cdei: Soils that are clayey throughout the depth and have moisture limitation with seed germi-nation problem when monsoon rains are erratic. They have low K reserve and low ability to retain plant nutrients mainly K, Ca and Mg; application of these and N fertilizers should be in split doses; These soils have high P-fixation capacity and require high level of P fertilizer or special P management practices. Source and method of P fertilizer application should be considered carefully; other limitations are high runoff potential, medium water-holding capacity and low infiltration rates.

Cdeaik: Soils that are clayey throughout the depth and have moisture limitation with seed germi-nation problem when monsoon rains are erratic, They have low K reserve and low ability to retain plant nutrients mainly K, Ca and Mg; application of these and N fertilizers should be in split doses. Plants sensitive to Al-toxicity will be affected unless lime is applied; Mn-toxicity may also occur in these soils. These soils have high P-fixation capacity and require high levels of P fertilizer or special P management practices—sources and method of P fertilizer application should be considered carefully. Other limitations are medium water-holding capacity, low infiltration capacity and high run off potential.

CC′dik: Soils that are clayey in surface layer and clayey with 15–35 per cent gravel in subsoil layers and have moisture limitation with seed germination problem when monsoon rains are erratic, low K reserve and high P-fixation capacity. They require high levels of P fertilizer or special P management practices—sources and method of P fertilizer application should be considered carefully. Other limitations are medium water-holding capacity, low infiltration rate and high runoff potential.

CC″deik: Soils that are clayey in surface soil and clayey with >35 per cent gravel in subsoil layers and have moisture limitation with seed germination problem when monsoon rains are erratic, low K reserve and low ability to retain plant nutrients mainly K, Ca and Mg. These and N fertilizers should be applied in split doses. These soils have high P-fixation capacity and require high levels of P fertilizer or special P management practices—

sources and methods of P fertilizer application should be considered carefully. Other limitations are medium water-holding capacity, low infiltration rate and high runoff.

C′C″deik: Soils that are clayey with 15–35 per cent gravel in the surface layer and clayey with >35 per cent gravel in subsoil layers and have moisture limitation with seed germination problem when monsoon rains are erratic, low K reserve and low ability to retain plant nutrients mainly K, Ca and Mg. These and N fertilizers should be applied in split doses. These soils have high P-fixation capacity and require high level of P fertilizer or special P management practices—sources and method of P fertilizer application should be considered carefully. Other limitations are medium water-holding capacity, low infiltration capacity and high runoff potential.

CL′dik: Soils that are clayey in the surface layer and loamy with 15–35 per cent gravel in subsoil layers and have moisture limitation with seed germination problem monsoon rains are erratic, low K reserve and high P-fixation capacity. They require high levels of P fertilizer or special P management practices—sources and method of P fertilizer application should be considered carefully. Other limitations are medium water holding capacity and low infiltration rate in surface layer and medium water-holding capacity and medium infiltration rate in the subsoil, high runoff potential.

2.3.5 Interpretation of suitability of soil map units for different crops

The major crops grown in Garakahalli watershed were horsegram (24.19%), groundnut (20.05%) and finger millet (7.57%) under rainfed conditions and, under irrigated conditions, finger millet (19.7%), rice (18.4%), banana (13.53%), mulberry (7.5%) and coconut (2.2%). The land suitability assessment of soil units for groundnut, finger millet, banana, mulberry and coconut is presented below.

Land suitability for finger millet (Table 2.15). All the soil-map units were interpreted for suita-bility for finger millet under rainfed conditions. The evaluation grouped the soils into highly suitable (4.7%), moderately suitable (76.22%), marginally suitable (1.53%) and not suitable (1.0%). Overall, 19

suitability units were demarcated with different kinds and degrees of limita-tions. The maximum area of 124.57 ha (23.63%) fell in unit S2tf with moderate limitations of soil texture and fertility. The second largest unit S2tfg2 with moderate limitations of soil texture (clay or loamy sand), fertility and gravel (>35%) in the subsoil constituted 11.24 per cent. The spatial distribution of the land suitability units is presented in Fig. 2.26.

Land suitability for groundnut (Table 2.16). All the soil mapping units were interpreted for rain-fed groundnut. The suitability evaluation has grouped the soils into highly suitable (6.4% area), moderately suitable (66.2%), marginally suitable (9.96%) and not suitable (1.0%). Overall 19 suitability units were demarcated with different kinds and degrees of limitations. About 17.69 per cent area was grouped under suitability unit S2tf with moderate limitations of surface soil texture (clayey) and soil fertility (CEC <8.0 cmol (+) kg^{-1}), and 16.53 per cent under land suitability unit S2tf with moderate limitation of soil fertility. The area grouped as not suitable was mainly on the basis of slope (>10%) or depth (<50 cm) limitation. The spatial distribution of land suitability units is presented in Fig. 2.27.

Land suitability for mulberry (Table 2.17). All the soil-mapping units were interpreted for suitability for mulberry crop (irrigated). The suitability evaluation grouped the soils into moderately suitable (69.40%), marginally suitable (1.39%) and not suitable (12.78%). Overall, 17 suitability units were demarcated with different kinds and degree of limitations. The largest area of 82.15 ha was rated as S2zfg2 with moderate limitations of soil fertility and subsoil gravelliness. About 15.31 per cent area (80.73 ha) was grouped under S2zfg2r3 with moderate limitations of soil fertility (CEC <15 cmol (+) kg^{-1}) and soil reaction (pH >8.0) and severe limitation of subsoil gravelliness(>35%). The area grouped as not suitable had mainly very severe limitations of depth (<50 cm) or gravelliness (>35%). The spatial distribution of the land suitability units is presented in Fig. 2.28.

Land suitability for banana (Table 2.18)

All the soil-mapping units were interpreted for suitability for banana (irrigated). The suitability evaluation showed that 80.13 per cent area was moderately suitable, 7.09 per cent area marginally suitable and 12.78 per cent area was not suitable due to severe limitations of either subsoil gravelliness (>35% gravel) or depth (<50 cm). Overall, 17 suitability units were demarcated with different kinds and degree of limitations. About 20 per cent area was grouped under S2tfg2 with moderate limitations of soil texture (clay), fertility and gravelliness. About 9 per cent area fell under suitability unit S2tfg3 with moderate limitations of soil texture and soil fertility and severe limitation of gravelliness(>35% gravel). Spatial distribution of the land suitability units is presented in Fig. 2.29.

Table 2.15 Land suitability of soil units for rainfed finger millet— Garakahalli watershed

Land suitability unit	***Soil map units***	***Area***	
		ha	%
S1	CcB1, ChB1, Cg2fB1, Cg1hB1	25.04	4.75
S2t	CbB1	16.44	3.12
S2f	IcB1, IhB1, IiB1, ImB1, ImB2, McB1, MhB1, NcB1, NhB1	44.45	8.43
S2r2	CcC2, CiC1	6.43	1.22
S2tf	EbB1, KbB1, KhB1, KmB1, Kg1hB1, NbB1, NiB1	124.57	23.63
S2tg2	FbB1	9.69	1.84
S2tr2	Cg1bc1, IbC1, IcCi, IiC2, Ig1hC1, Ig2hC2St3	14.29	2.71
S2fg2	Eg1iB1, Eg1cB1St3, Eg1hB1–R, GbB1	14.50	2.75
S2tfg2	BmB1, BcB1, EmB1, FcB1, FhB1, FiB1, GbB2, GcB1, JhB1, Jg1hD2St3	59.25	11.24
S2tfg3	DmB1, Dg1bB1, Dg1bB1St3, Dg1cC1, HbB1, HcB1, HhB1, Hg1bB1, Hg2bB1, Hg1hB1, Hg1iB1, HcB1St3	35.95	6.82
St2fr2	KcC1, KhC1, KiC1, KbC2, Kg1cB1, Kg1hC2St4–R	26.13	4.96
St2fr3	Kg2hD2St4–R, KhD2, KhD2St3	15.31	2.90
S2fg2r2	Eg2cC2St4, Gg1iC1, Gg1hC1St3, Gg2hC1St3, GbC2St3–R	11.92	2.26
S2tfg3r3	Gg2cD2St4–R	2.03	0.39
S2tfg3r2	Hg2cD2St3, Hg1cD2St4, Hg1hD2St4, Hg2hD2St4	13.08	2.48

S3fg3r3	Hg1iC1, Hg2iC1, HmC1St3	8.17	1.55
S3tg3r2	Lg1cD2St3	2.82	0.53
S3fg2r3	Lg1bC2St3	5.28	1.00
N	Ag2hD2St4, Gg1cE3St4, Gg1hE3St4	5.29	1.00

Key:

Suitability class

S1 — highly suitable; S2 — moderately suitable; S3 — marginally suitable;

N — not suitable

Limitations:

g = gravelliness—g2, 15–35% gravel; g3, >35% gravel

f = fertility—CEC <8 cmol (+) kg^{-1}

t = texture—clayey

r = relief—r2, 3–5% slope; r3, 5–10% slope

z = soil reaction—pH >8.0

Table 2.16 Land suitability of soil units for rainfed groundnut— Garakahalli watershed

Land suitability unit	***Soil map units***	***Area***	
		ha	%
S1	CbB1, CcB1	33.93	6.44
S2f	EbB1, Eg1cB1St3, FbB1, FcB1, GbB1, GbB2, GcB1, BcB1, IcB1, KbB1, KcB1, McB1	93.28	17.69
S2t	Cg1hB1, Cg2fB1, ChB1, BNbB1, NcB1, NhB1, NiB1	37.61	7.13
S2tr2	Cg1bC1, CcC2, CiC1	9.13	1.73
S2tf	EmB1, Eg1iB1, Eg1hB1–R, FhB1, FiB1, IhB1, IiB1, KhB1, MhB1	87.13	16.53
S2tfg2	DmB1, Dg1bB1, Dg1bB1St3	6.42	1.22
S2fr2	Dg1cC1, Eg2cC2St4, GbC2St3–R, IbC1, IcC1	12.75	2.42
S2tfr2	Gg1iC1, Gg1hC1St3, Gg2hC2St3, IiC2, IgihC1	7.89	1.50
S2fg2z	HbB1, HcB1, HhB1, Hg1bB1, Hg2bB1, HcB1St3	21.19	4.02

S2tfr2z	Ig2hC2St3, KhC1, KiC1, Kg1hC2St4–R	17.18	3.26
S2tfg2z	Hg1hB1, Hg1iB1, Hg1iC1, Hg2iC1, HmC1St3	14.33	2.72
S3tf	BmB1, ImB1, ImB2	12.19	2.31
S3fr3	Gg2cD2St4–R, Hg2cD2St3, Hg1cD2St4, Lg1bC2St3, Lg1cD2St3	16.69	3.17
S3fg2r3	Kg2hD2St4–R, Jg1D2St3, KhD2, KhD2St3	17.07	3.24
S3tfr3	Hg1hD2St4, Hg2hD2St4	6.53	1.24
N	Ag2hD2St4, Gg1cE3St4, Gg1hE3St4	5.29	1.00

Key: Suitability class

S1 — highly suitable; S2 — moderately suitable; S3 — marginally suitable;

N — not suitable

Limitations: g = gravelliness—g2, >35% gravel
f = fertility—CEC <8 cmol (+) kg^{-1}
t = texture—clayey
r = relief—r2, 3–5% slope; r3, 5–10% slope
z = soil reaction—pH >8.0

Table 2.17 Land suitability of soil units for mulberry cultivation — Garakahalli watershed

Land suitability unit	***Soil map units***	***Area***	
		ha	%
S2df	Cg2fB1, CbB1, CcB1, ChB1, Cg1hB1	41.48	7.87
S2zf	McB1	0.97	0.18
S2dfg2	IcB1, IhB1, IiB1, ImB1, ImB2	18.36	3.48
S2dfr2	CcC2, CiC1, Cg1bC1	9.13	1.73
S2zfr2	Kg1hC2St4–R	4.50	0.85
S2zfg2	KbB1, KhB1, KmB1, Kg1hB1	82.15	15.58
S2dtzf	MhB1, NbB1, NcB1, NhB1, NiB1	40.48	7.68
S2ztg2	KcB1	22.77	4.32

S2dfzg2	EbB1, EmB1, Eg1iB1, Eg1cBSt3, Eg1hB1–R, FbB1, FcB1, FhB1, FiB1, GbB1, GcB1, Gg1iC1, Gg1hC1St3, JhB1, JiB1	80.73	15.31
S2dfg2r2	IbC1, IcC1, IiC2, Ig1hC1, Ig2hC2St3	11.59	2.20
S2zfg2r2	KcC1, KhC1, KiC1, KbC2, Kg1cB1	21.63	4.11
S2zfg2r3	Kg2hD2St4–R, KhD2, KhD2St3	15.31	2.90
S2dfzr2g2	Gg2hC2St3, Eg2cC2St3, GbC2St3–R	9.81	1.86
S2dfr3g2	Gg1cE3St4, Gg1hE3St4, Gg2cD2St4–R	5.25	1.00
S2dfzg2r3	Jg1hD2St3	1.76	0.33
S3dfg2	BmB1, BcB1	7.35	1.39
N	Ag2hD2St4, DmB1, Dg1bB1, Dg1bB1St3, Dg1cC1, HbB1, HcB1, HhB1, Hg1bB1, Hg2bB1, Hg1hB1, Hg1iB1, Hg1iC1, Hg2iC1, HcB1St3, HmC1St3, Hg2cD2St3, Hg1cD2St4, Hg1hD2St4, Hg2hD2St4, Lg1bC2St3, Lg1cD2St3	67.38	12.78

Key: Suitability class

S2 — moderately suitable; S3 — marginally suitable; N — not suitable

Limitations: g = gravelliness—g2, 15–35% gravel

f = fertility—CEC <8 cmol (+) kg^{-1}

d = rooting depth—<150 cm

r = relief—r2, 3–5% slope; r3, 5–10% slope

z = soil reaction—pH >8.0

Table 2.18 Land suitability of soil units for banana cultivation — Garakahalli watershed

Land suitability unit	***Soil map units***	***Area***	
		ha	%
S2d	Cg2fB1, CbB1, CcB1, ChB1, Cg1hB1	41.48	7.87
S2f	McB1, MhB1	11.38	2.16
S2dr2	CcC2, CiC1, Cg1bC1	9.13	1.73
S2fg2	IcB1, IhB1, IiB1, ImB1, ImB2	18.36	3.48
S2dfg3	EbB1, EmB1, Eg1iB1, Eg1cB1St3, Eg1hB1–R, GbB1, GbB2, GcB1	31.72	6.02
S2tfg2	KbB1, KcB1, KhB1, KmB1, Kg1hB1	104.92	19.90
S2fg2r2	IbC1, IcC1, IiC2, Ig1hC1, Ig2hC2St3	11.59	2.20
S2tfg3	FbB1, FcB1, FhB1, FiB1, JhB1, JiB1	46.90	8.90
S2dfrg3	Eg2cC2St4, Gg1iCi, Gg1hC1St3, Gg2hC2St3	7.95	1.51
S2dfr2g3	GbC2St3–R	3.98	0.75
S2dfr3g3	Gg1cE3St4, Gg1hE3St4, Gg2cD2St4–R	5.25	1.00
S2tfg2r3	Kg2hD2St4–R, KhD2, KhD2St3	15.31	2.90
S2tfg3r3	Jg1hD2St3	1.76	0.33
S2tfg2r2	KcC1, KhC1, KiC1, KbC2, Kg1cB1, Kg1hC2St4–R	26.13	4.96
S3tf	NbB1, NcB1, NhB1, NiB1	30.07	5.70
S3dfg3	BmB1, BcB1	7.35	1.39
N	Ag2hD2St4, DmB1, Dg1bB1, Dg1bB1St3, Dg1cC1, HbB1, HcB1, HhB1, Hg1bB1, Hg2bB1, Hg1hB1, Hg1iB1, Hg1iC1, Hg2iC1, HcB1St3, HmC1St3, Hg2cD2St3, Hg1cD2St4, Hg1hD2St4, Hg2hD2St4, Lg1bC2St3, Lg1cD2St3	67.38	12.78

Key: Suitability class

S2 — moderately suitable; S3 — marginally suitable; N — not suitable

Limitations: g = gravelliness—g2, 15–35% gravel; g3, >35% gravel

d = rooting depth—<150 cm

f = fertility—CEC <8 cmol (+) kg^{-1}

d = rooting depth—<150 cm

r = relief—r2, 3–5% slope; r3, 5–10% slope

t = texture—clayey

z = soil reaction—pH >8.0

Land suitability for coconut (Table 2.19). All the soil-mapping units were interpreted for suita-bility for coconut. The suitability evaluation indicated that 54.86 per cent area was highly suitable, 41.55 per cent area moderately suitable, 16.77 per cent area marginally suitable and about 2.07 ha (0.39%) not suitable due to depth limitation. Overall, 17 suitability units were demarcated with different kinds and degree of limitations. About 10.59 per cent area, grouped under S2dg2 had moderate limitations of soil depth (<150 cm) and subsoil gravelliness (15–35% gravel). The second largest suitability unit S3d covered 9.60 per cent area and had severe depth limitation (<100 cm depth). The spatial distribution of the land suitability units is presented in Fig. 2.30.

Table 2.19 Land suitability of soil units for coconut cultivation — Garakahalli watershed

Land suitability unit	***Soil map units***	***Area***	
		ha	%
S1	KbB1, KcB1, KhB1, KmB1, KcC1, KhC1, KiC1, KbC2, Kg1cB1, Kg1hB1, Kg1hC2St4–R	131.05	24.86
S2d	IcB1, IhB1, IiB1, ImB1, ImB2, IbC1, IcC1, IiC2, Ig1hC1, Ig2hC2St3	29.95	5.68
S2r	Kg2hD2St4–R, KhD2, KhD2St3	15.31	2.90
S2g3	Lg1bC2St3	5.28	1.00
S2z	McB1, MhB1	11.38	2.16
S2dg2	FbB1, FcB1, FhB1, FiB1, GbB1, GbB2, GcB1, Gg1iC1, Gg1hC1St3, Gg2hC2St3	55.80	10.59
S2dg3	Gg2cD2St4–R, HbB1, HcB1, HhB1, Hg1bB1, Hg2bB1, Hg1hB1, Hg1iB1, Hg1iC1, Hg2iC1, HcB1St3, HmC1St3	37.55	7.12
S2dtz	NbB1, NcB1, NhB1, NiB1	30.07	5.70
S2dg2r	Gg1cE3St4, Gg1hE3St4, GbC2St3–R, Jg1hD2St3	8.96	1.70
S2dg3r	Hg2cD2St3, Hg1cD2St4, Hg1hD2St4, Hg2hD2St4	13.08	2.48
S2g3rz	Lg1cD2St3	2.82	0.53
S2dg2z	JhB1, JiB1	8.90	1.69
S3d	Cg1bC1, Cg1hB1, Cg2fB1, CbB1, CcB1, CcC2, ChB1, CiC1	50.61	9.60
S3dg2	BcB1, BmB1, EbB1, EmB1, Eg1iB1, Eg1cB1St3, Eg2cC2St4, Eg1hB1–R	29.22	5.54
S3dg3	DmB1, Dg1bB1, Dg1bB1St3, Dg1cC1	8.61	1.63

N	Ag2hD2St4	2.08	0.39

Key: Suitability class

S2 — moderately suitable; S3 — marginally suitable; N — not suitable

Limitations: g = gravelliness—g2, 15–35% gravel; g3, >35% gravel

f = fertility—CEC <8 cmol (+) kg^{-1}

d = rooting depth—<150 cm

r = relief—>5% slope

t = texture—clayey

z = soil reaction—pH >8.0

Table 2.1 Identifying characteristics of the soil series of Garakahalli microwatershed

Series	Depth, cm	Texture	Gravel, %	Colour (moist)	Physiography	Drainage	Horizon sequence	Substratum
A	10–25	gsl–gscl	70	7.5YR 3/4	Moderately sloping land	Welldrained	A–R	Hard rock
B	50–75	scl–gc	0–30	2.5YR 3/4, 3/6	Gently sloping lands	Welldrained	Ap–Bt-Cr	Weathered parent material
C	75–100	sc, gsc, c, gc	0–35	5YR 3/4, 4/4, 4/6; 2.5YR 3/6, 4/6	Very gently sloping and gently sloping lands	Welldrained	Ap–Bt-Cr	Weathered parent material
D	75–100	c–gc	>35 at 15–50 cm	2.5YR 3/6	Gently sloping	Welldrained	Ap–Bt-Cr	Weathered parent material
E	75–100	gsc–sc	<35	7.5YR 5/8, 4/6; 5YR 4/4, 4/6; 2.5YR 3/6, 4/6	Gently sloping lands	Welldrained	Ap–Bt-Cr	Weathered parent material
F	100–150	sc–gsc, gc–c	50–70 below 50 cm	7.5YR 4/4; 5YR 4/4, 4/6; 2.5YR 3/4, 3/6, 4/6	Very gently sloping lands	Welldrained	Ap–Bt-Cr	Weathered parent material
G	100–150	scl–sc–gsc	15–35	7.5YR 4/4; 5YR 3/4, 4/4, 5/6; 2.5YR 3/4, 3/6, 4/6	Gently sloping and moderately sloping lands	Welldrained	Ap–Bt-Cr	Weathered parent material
I	100–150	c	—	2.5YR 3/4	Gently sloping lands	Welldrained	Ap–Bt-Cr	Weathered parent material
J	100–150	scl–c–gc	40–60 below 60 cm	5YR 3/3, 3/4, 4/4; 2.5YR 3/4, 3/6	Very gently sloping lands	Welldrained	Ap–Bt-Cr	Weathered parent material
K	>150	scl–sc, gsc, c–gc	45–70 below 80 cm	7.5YR 4/4, 5/4; 5YR 4/4, 3/3, 3/4; 2.5YR 3/4, 3/6	Very gently sloping and gently sloping lands	Welldrained	Ap–Bt	—
L	>150	c–gc	>35	2.5YR 3/4, 3/6	Gently sloping and moderately sloping lands	Welldrained	Ap–Bt	—
M	>150	sl–scl–sc–c	—	7.5YR 3/4; 5YR 3/3, 3/4, 4/4, 5/8	Very gently sloping and gently sloping lands	Moderately well drained and welldrained	Ap–Bt	—
N	>150	s–ls, sl, scl, sc–c	—	5YR 3/3, 4/4, 4/6, 5/6, 5/8; 2.5YR 3/6, 4/6	Very gently sloping lands	Moderately well drained and welldrained	Ap–Bw	—

Table 2.2 Morphological features of soil series of Garakahalli microwatershed

Depth cm	Horizon	Colour (moist)	Coarse frag. % by volume	Texture	Structure	Consistence	Special features
				Soil series A			
0–14	A	7.5YR 3/4	70	gsl	m1sbk	sh, fr, ss, sp	
14–55	R	Hard granite					
				Soil series B			
0–18	Ap	2.5YR 4/6	5	scl	m1sbk	fr, ss, sp	tmtkc; fc conir
18–42	Bt	2.5YR 3/4	10	sc	m2sbk	fr, s, p	
42–75	BC	2.5YR 3/6	30	gscl	m1sbk	fr, ss, sp	
75–95	Cr	Weathered granite					
				Soil series C			
0–13	Ap	5YR 3/4	10	sl	m1sbk	l, vfr, ss, sp	f f conir
13–40	Bt1	2.5YR 3/6	0	sc	m2sbk	sh, fr, sp	tmtkc; f f conir
40–58	Bt2	2.5YR 3/6	15	c	m2sbk	sh, fr, sp	tmtkc; f f conir
58–83	BC	5YR 4/4	0	sl	m1sbk	sh, fr, ss, sp	
83–110	Cr	Weathered granite					
				Soil series D			
0–14	Ap	2.5YR 4/6	5	scl	m1sbk	sh, fr, ss, sp	tmtkc
14–37	Bt1	2.5YR 3/6	10	c	m2sbk	sh, fr, sp	tmtkc; mm conir
37–63	Bt2	2.5YR 3/6	70	gc	m2sbk	sh, fr, sp	tmtkc; mm conir
63–89	2Bt3	2.5YR 3/6	15	cl	m2sbk	fr, sp	
89–148	Cr	Weathered granite					

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Depth cm	Horizon	Colour (moist)	Coarse frag. % by volume	Texture	Structure	Consistence	Special features
				Soil series E			
0–7	Ap	5YR 5/4	30	gscl	m1sbk	sh, fr, ss, sp	
7–30	Bt1	2.5YR 4/6	30	gscl	m2sbk	fr, ss, sp	ttnc; ff conir
30–51	Bt2	2.5YR 4/6	20	gscl	m2sbk	fr, ss, sp	ttnc; ff conir
51–72	2Bt3	5YR 4/6	50	gscl	m2sbk	fr, ss, sp	ttnc; ff conir
72–96	Bc	7.5YR 5/8	20	gsl	m1sbk	fr, ss, sp	ff conir
96–110	Cr	Weathered granite					
				Soil series F			
0–15	Ap	7.5YR 4/4	10	scl	f 1, gr	ll, s0, p0	
15–52	Bt1	2.5YR 3/4	5	sc	m2sbk	fr, sp	tmtk c
52–75	Bt2	2.5YR 3/6	5	sc	m2sbk	fr, sp	tmtk c
75–106	2Bt3	2.5YR 3/6	50	gsc	m1sbk	fr, sp	ttn c
106–130	2Bc	2.5YR 4/6	30	gscl	m1sbk	fr, ss, sp	ttn c
130–145	2Cr	Weathered granite					
				Soil series G			
0–16	Ap	5YR 3/3	50	gsl	f1sbk	l, ss, p0	
16–48	Bt	2.5YR 3/6	30	gscl	m1sbk	fr, ss, sp	ttnc
48–84	Bc1	2.5YR 3/6	25	gsl	m1sbk	fr, ss, sp	ttnb
84–106	Bc2	5YR 3/4	15	gls	m1sbk	fr, s0, p0	
106	Cr	Weathered granite					

Soil series H

0–10	Ap	2.5YR 3/6	25	gscl	m1sbk	l, fr, ss, sp	
10–29	Bt	2.5YR 3/6	15	gscl	m2sbk	sh, fr, ss, sp	t mtk c
29–45	Bt2	2.5YR 3/6	60	gsc	m1sbk	sh, fr, sp	t mtk b
45–84	Bt3	2.5YR 3/4	50	gsc	m1sbk	sh, fr, sp	t mtk b
84–122	Bt4	2.5YR 3/4	35	gsc	m1sbk	sh, fr, sp	t mtk b
122–144	Bt5	2.5YR 3/4	40	gscl	m1sbk	fr, sp	t mtk b
144–157	Cr	Weathered granite					

Soil series

0–10	Ap	2.5YR 3/6	0	sl	m1sbk	sh, fr, ss, sp	ff conir
10–44	Bt	2.5YR 3/4	0	scl	m2sbk	sh, fr, ss, sp	tmtkc; ff conir
44–77	Bt2	2.5YR 3/4	0	scl	m2sbk	sh, fr, sp	tmtkc; ff conir
77–109	Bt3	2.5YR 3/4	0	scl	m2sbk	sh, fr, sp	tmtkc; ff conir
109–130	BC	2.5YR 3/4	70	gls	m1sbk	sh, fr, s0, p0	f c conir
130	Cr	Weathered granite					

Soil series J

0–12	Ap	7.5YR 4/4	10	sl	m1sbk	l, vfr, ss, sp	ff conir
12–33	Bt	5YR 4/4	0	scl	m1sbk	sh, fr, ss, sp	tmtkc; fc conir
33–60	Bt2	5YR 3/4	0	sc	m2sbk	fr, sp	ttnc; ff conir
60–94	Bt3	2.5YR 3/6	40	gsc	m1sbk	fr, sp	tmtkc; ff conir
94–130	Bt4	5YR 3/4	20	gscl	m2sbk	fr, ss, sp	tmtkc, fc conir
130–150	Cr	Weathered granite					

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Depth cm	Horizon	Colour (moist)	Coarse frag. % by volume	Texture	Structure	Consistence	Special features
				Soil series K			
0–10	Ap	5YR 4/4	10	sl	m1sbk	l, vfr, ss, sp	
10–40	Bt	2.5YR 3/6	0	scl	m2sbk	fr, ss, sp	tmtkc
40–69	Bt2	2.5YR 3/4	0	sc	m2sbk	fr, sp	tmtkc
69–98	Bt3	2.5YR 3/4	10	sc	m2sbk	fr, sp	tmtkc
98–133	2Bt4	2.5YR 3/6	50	gscl	m1sbk	fr, ss, sp	tmtkb
133–151	2Bt5	2.5YR 3/6	0	cl	m2sbk	fr, ss, sp	tmtkb
				Soil series L			
0–8	Ap	2.5YR 4/6	15	gsl	m1sbk	l, vfr, ss, p0	
8–25	Bt	2.5YR 3/6	15	gscl	m2sbk	sh, fr, ss, sp	tmtkp; ff conir
25–56	Bt2	2.5YR 3/4	70	gsc	m1sbk	sh. fr, sp	ttnb; ff conir
56–79	Bt3	2.5YR 3/4	65	gsc	m1sbk	sh. fr, sp	ttnb; ff conir
79–104	Bt4	2.5YR 3/4	60	gcl	m1sbk	sh. fr, sp	tmtkb
104–136	Bt5	2.5YR 3/4	50	gscl	m1sbk	sh. fr, sp	tmtkb
136–164	BC	2.5YR 3/6	50	gls	m1sbk	fr, s0, p0	
				Soil series M			
0–14	Ap	7.5YR 3/4	0	sl	m1sbk	vfr, s0, p0	ttnc, ff conir
14–28	Bt1	7.5YR 3/4	0	sl	m1sbk	fr, s0, p0	ttnc, ff conir
28–53	Bt2	5YR 4/4	0	sl	m1sbk	fr, ss, p0	tmtkc, ff conir
53–89	Bt3	5YR 3/4	0	scl	m2sbk	fr, ss, sp	tmtkc
89–121	Bt4	5YR 3/4	0	scl	m2sbk	fr, ss, sp	tmtkc
121–154	Bt5	5YR 4/4	0	scl	m2sbk	fr, ss, sp	

Soil series N

0–11	Ap	5YR 4/4	0	scl	m1sbk	sh, fr, ss, sp	ff conir
11–30	AC1	5YR 3/4	0	sl	m2sbk	fr, s0, p0	ff conir
30–52	C	5YR 4/4	0	s	sg	l, s0, p0	
52–86	2A	2.5YR 4/6	0	sl	f1sbk	vfr, s0, p0	
96–119	2Bw1	2.5YR 3/6	0	sl	m1sbk	fr, ss, sp	
119–150	2Bw2	2.5YR 3/6	0	scl	m2sbk	fr, ss, sp	

Table 2.3 Physical and chemical properties of the soils of Garakahalli microwatershed

Depth cm	Horizon	Particle size distribution			Coarse frag.	Texture (USDA)	Organic C	$CaCO_3$ equiv.	pH (H_2O) 1:2.5	ECe 1:2.5	Exchangeable bases				CEC (NH_4OAc)	Base satn
		Sand	Silt	Clay							Ca	Mg	Na	K		
		% of <2 mm			vol. %		%				cmol (+) kg^{-1}					%
							Series A									
0–14	A	64.7	13.1	22.2	70	gsl	1.21	0	6.3	0	2.9	2.5	0.0	0.6	7.0	59
							Series B									
0–18	Ap	65.1	7.9	27.0	5	scl	0.37	0	6.8	0	5.1	1.8	0.0	0.2	9.9	72
18–42	Bt1	46.0	12.4	41.6	10	sc	0.83	0	7.1	0	10.3	2.1	0.1	0.1	16.8	75
42–75	Bt2	61.6	12.3	26.1	30	gscl	0.21	0	7.5	0	7.8	1.3	0.1	0.1	12.2	76
							Series C									
0–13	Bt2	70.3	13.1	16.6	10	sl	0.19	0	6.8	0	6.5	1.7	0	0.1	10.3	81
13–40	Bt1	49.3	15.6	35.1	0	sc	0.32	0	6.5	0	10.9	3.8	0.1	0.1	18.3	81
40–58	Ap	40.3	19.7	40.0	15	c	0.42	0	6.6	0	10.8	4.4	0	0.1	19.0	81
58–83	Bt3	77.3	14.5	8.2	0	sl	0.11	0	8.3	0.16						
							Series D									
0–14	Ap	56.9	10.6	32.5	5	scl	0.45	0	7.3	0.13	6.4	1.8	0.5	0.2	13.2	67
14–37	Bt1	26.9	29.3	43.8	10	c	0.32	0	7.3	0	7.0	2.0	0.4	0.1	15.6	61
37–63	2Bt2	43.5	14.9	41.6	70	gc	0.26	0	7.2	0	7.7	2.1	0.9	0.1	16.8	64
63–89	3Bt3	44.0	17.4	38.6	15	cl	0.24	0	7.2	0	8.0	2.0	0.9	0.1	17.1	64

... contd

Depth	Horizon	Particle size distribution			Coarse	Texture	Organic	$CaCO_3$ equiv.	pH (H_2O)	ECe	Exchangeable bases				CEC	Base
		Sand	Silt	Clay	frag.	(USDA)	C		1:2.5	1:2.5	Ca	Mg	Na	K	(NH_4OAc)	satn
cm		% of <2 mm			vol. %		%				cmol (+) kg^{-1}					%
Series E																
0–7	Ap	60.6	16.2	23.2	30	gscl	0.31	0	6.4	0	4.8	4.4	0.1	0.1	10.1	53
7–30	Bt1	59.4	12.2	28.4	30	gscl	0.30	0	6.8	0	4.6	4.4	0.1	0.1	10.0	52
30–51	Bt2	55.8	12.9	31.3	20	gscl	0.31	0	6.8	0	6.3	4.4	0.3	0.1	11.6	61
51–72	Bt3	61	14.2	24.8	50	gscl	0.19	0	7.0	0	5.5	4.4	0.3	0.1	11.1	57
72–96	Bt4	67.2	13.7	19.1	20	gsl	0.24	0	7.1	0.05	4.3	0.3	0.2	0.1	9.6	51
Series F																
0–15	Ap	47.3	18.5	34.2	10	scl	0.28	0	6.3	0	2.0	0.4	0.4	0.1	3.6	81
15–52	Bt1	49.6	9.4	41.0	5	sc	0.38	0	6.9	0.08	5.1	0.8	0.5	0.1	11.5	57
52–75	Bt2	47.4	10.5	42.1	15	sc	0.39	0	6.7	0	5.6	0.9	0.4	0.1	12.1	58
75–106	2Bt3	45.5	7.9	46.6	50	gsc	0.25	0	6.4	0.07	6.0	0.9	0.6	0.1	12.9	59
106–130	2Bt4	56.5	11.7	31.8	30	gscl	0.18	0	6.5	0	5.6	0.7	0.5	0.1	10.9	63
Series G																
0–16	A	79.3	10.5	10.2	50	gsl	0.76	0	6.2	0.17	2.7	1.7	0	0.4	7.0	69
16–48	Bt1	58.9	13.9	27.2	30	gscl	0.50	0	6.4	0.07	3.8	2.1	0	0.1	9.0	67
48–84	Bt2	64.9	15.5	19.6	25	gsl	0.28	0	6.6	0.05	4.7	2.7	0	0.1	7.5	100
84–106	Bt3	77.3	17.7	5.0	15	gls	0.14	0	6.7	0.50	5.0	2.8	0	0.1	8.0	99

Series H																
0–10	Ap	69.9	8.6	21.5	25	gscl	0.50	0	5.9	0.07	2.3	0.4	0.4	0.1	6.3	51
10–29	Bt1	60.1	8.9	31.0	15	gscl	0.43	0	5.8	0.07	3.3	0.4	0.5	0.1	8.3	52
29–45	2Bt2	50.7	9.0	40.3	60	gsc	0.48	0	6.3	0.06	4.0	0.5	0.5	0.1	10.1	50
45–84	2Bt3	48.3	9.8	41.9	50	gsc	0.33	0	6.7	0.07	3.2	5.3	0.2	0.1	9.5	93
84–122	2Bt4	45.9	14.5	39.6	35	gsc	0.28	0	6.3	0.07	5.0	0.5	0.2	0.1	12.2	48
122–144	2Bt5	49.2	16.1	34.7	40	gscl	0.25	0	6.6	0.0	8.5	1.1	0.3	0.1	16.6	60
Series I																
0–10	Ap	73.1	7.7	19.2	0	sl	0.24	0	6.5	0.08	2.3	1.7	0	0.3	6.0	72
10–44	Bt2	49.4	26.1	24.5	0	scl	0.32	0	6.4	0.07	5.6	3.7	0.1	0.1	11.5	83
44–77	Bt1	51.6	16.8	31.6	0	scl	0.37	0	6.0	0.06	3.8	2.9	0	0.2	9.6	72
77–109	Bt3	47.4	21.7	30.9	0	scl	0.30	0	6.8	0.07	6.9	4.0	0.1	0.1	11.9	93
109–130	Bt4	50.4	39.8	9.8	70	gls	0.36	0	6.9	0	5.5	3.2	0	0.1	10.7	82
Series J																
0–12	Bt1	67.6	15.5	16.9	0	sl	0.46	0	8.2	0	5.9	3.4	0.2	0.2	10.5	92
12–33	Ap	64.9	13.4	21.7	0	scl	0.53	0	8.3	0.16	5.3	2.9	0.2	0.2	9.4	91
33–60	Bt2	49.5	9.6	40.9	0	sc	0.34	0	8.2	0	8.3	4.6	0.4	0.1	15.1	89
60–94	Bt3	48.5	11.6	39.9	0	gsc	0.38	0	8.2	0	9.2	4.6	0.4	0.1	16.8	85
94–130	Bt4	47.0	19.2	33.8	0	gscl	0.17	0	8.1	0.22	8.2	4.0	0.5	0.1	14.2	90

... contd

Depth	Horizon	Particle size distribution			Coarse	Texture	Organic	$CaCO_3$ equiv.	pH (H_2O)	ECe	Exchangeable bases				CEC	Base
cm		Sand	Silt	Clay	frag.	(USDA)	C		1:2.5	1:2.5	Ca	Mg	Na	K	(NH_4OAc)	satn
		% of <2 mm			vol. %		%				cmol (+) kg^{-1}					%
Series K																
0–10	Ap	79.1	7.4	13.5	2	sl	0.41	0	5.9	0	2.2	0.3	0.1	0.1	5.5	49
10–40	Bt2	50.0	17.7	32.3	11	scl	0.39	0	6.7	0	6.2	0.5	0.3	0.1	13.5	53
40–69	Bt1	45.6	12.4	42.0	1	sc	0.50	0	6.8	0	6.1	0.5	0.3	0.1	13.4	52
69–98	Bt3	48.4	11.0	40.6	0	sc	0.65	0	6.4	0.08	5.4	0.4	0.2	0.1	12.9	47
98–133	2Bt4	50.6	14.5	34.9	34	gscl	0.32	0	6.9	0	6.3	0.5	0.3	0.1	13.8	52
133–151	3Bt5	44.0	20.9	35.1	11	cl	0.28	0	6.8	0	9.2	0.5	0.3	0.1	18.0	56
Series L																
0–8	Ap	74.7	12.8	12.5	15	gsl	0.37	0	6	0	3.1	0.5	0.3	0.1	7.1	56
8–25	Bt1	55.5	15.4	29.1	18	gscl	0.49	0	6.2	0.16	7.5	1.2	0.4	0.1	13.9	66
25–56	Bt2	51.6	12.1	36.3	76	gsc	0.38	0	7.0	0.12	9.0	1.4	0.4	0.1	15.4	71
56–79	Bt3	45.1	9.0	45.9	73	gsc	0.44	0	7.6	0	9.6	1.2	0.5	0.1	16.5	69
79–104	Bt4	44.2	18.0	37.8	73	gcl	0.31	0	8.2	0.16						
104–136	Bt5	47.5	19.2	33.3	59	gscl	0.35	5	8.2	0.18						
136–164	Bt6	83.1	8.2	8.7	68	gls	0.28	0	8.4	0.17						

Series M

0–14	Ap	73.6	13.5	12.9	6	sl	0.53	0	6.6	0.20	5.3	1.8	0.4	0.1	7.7	99
14–28	Bt1	74.1	14.6	7.3	7	sl	0.43	0	7.2	0.20	5.9	1.4	0.3	0.1	7.1	100
28–53	Bt2	71.6	11.4	17.0	7	sl	0.13	0	7.8	0.12	5.6	1.8	0.3	0.1	7.9	100
53–89	Bt3	47.2	27.2	25.6	5	scl	0.17	7	8.8	0						
89–121	Bt4	51.6	21.1	27.3	5	scl	0.18	4	8.3	0						
121–154	Bt5	68.3	8.0	23.7	6	scl	0.12	0	7.6	0	4.2	1.8	0.4	0.1	10.6	61

Series N

0–11	Ap	61.2	13.2	25.6	9	scl	0.43	0	7.5	0.20	5.5	0.6	0.4	0.5	12.3	57
11–30	Bw	73.6	10.4	16.0	15	sl	0.37	0	7.5	0	3.5	0.5	0.3	0.2	9.0	50
30–52	C	94.5	2.4	3.1	22	s	0.10	0	7.8	0	0.9	0.2	0.1	0	2.0	60
52–86	2Bw1	81.1	7.7	11.2	10	sl	0.11	0	8.0	0	2.8	0.2	0.2	0.1	5.9	58
86–119	3Bw2	62.0	18.1	19.9	9	sl	0.11	0	8.3	0.19						
119–150	3Bw3	58.6	16.8	24.6	7	scl	0.19	1	8.4	0.19						

Table 2.4 Soil and site characteristics of the soil phases of Garakahalli microwatershed

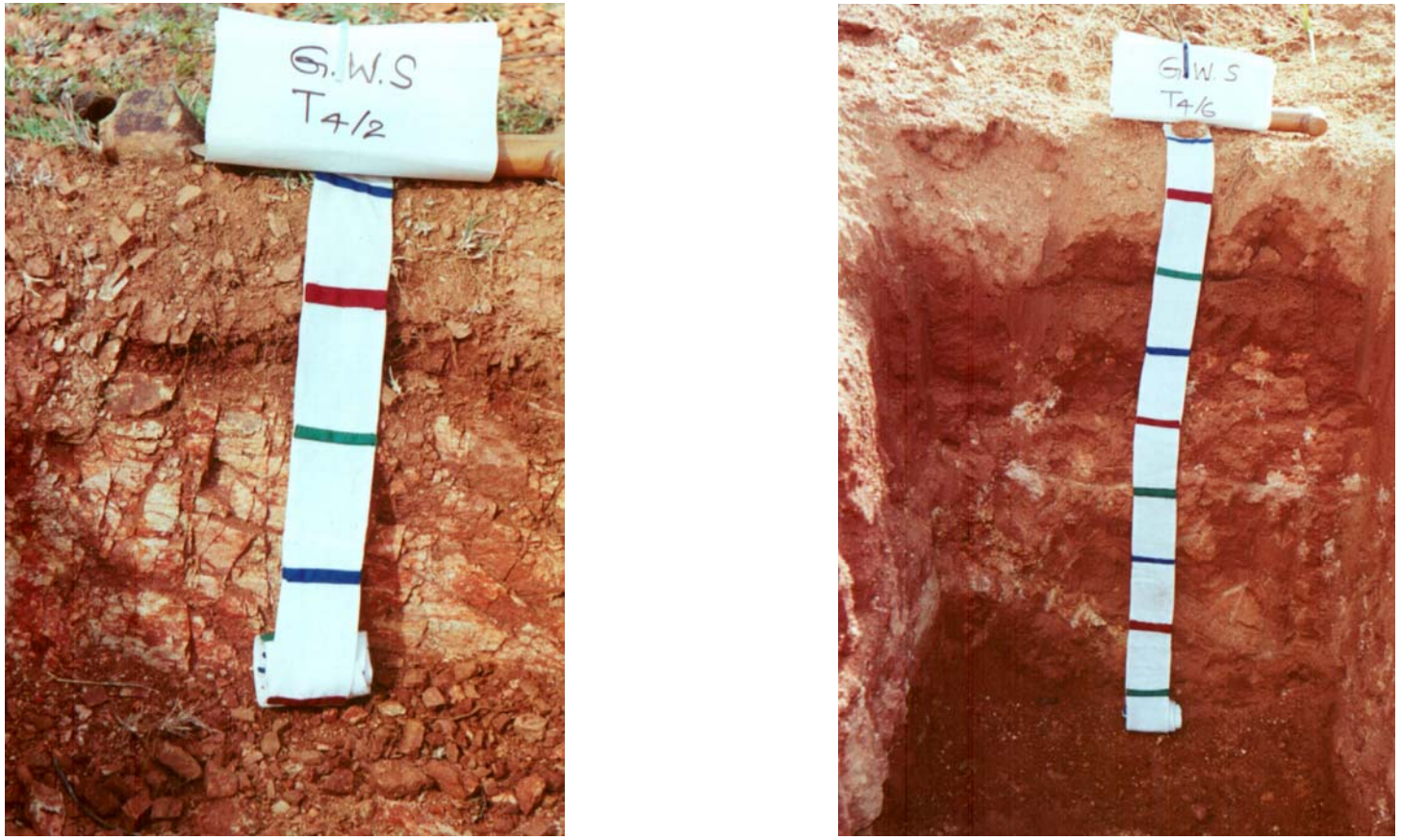
Soil phase	Slope	Erosion	Stoniness/gravelliness		Depth	Texture		pH		Organic C	CEC	Base satn
	(%)		Surface	Subsoil	cm	Surface	Profile	Surface	Profile	(%)	(cmol (+) kg^{-1})	(%)
Ag2hD2st4	5–10	e2	>35	>35	14	gscl	gscl	6.3	6.3	0.21	7.0	86
BmB1	1–3	e1	5	15–35	75	c	scl	6.9	7.3	0.37	9.9	72
BcB1	1–3	e1	5	15–35	75	sl	scl	6.8	6.3	0.37	9.9	72
Cg2fB1	1–3	e1	15	–	83	cl	scl	6.6	7.2	0.42	19.0	81
CbB1	1–3	e1	15	–	83	ls	scl	6.6	7.2	0.42	19.0	81
CcB1	1–3	e1	15	–	83	sl	scl	6.6	7.2	0.42	19.0	81
CcC2	3–5	e2	15	–	83	sl	scl	6.6	7.2	0.42	19.0	81
ChB1	1–3	e1	15	–	83	scl	scl	6.6	7.2	0.42	19.0	81
CiC1	3–5	e1	15	–	83	sc	scl	6.6	7.2	0.42	19.0	81
Cg1bC1	3–5	e1	15	–	83	ls	scl	6.6	7.2	0.42	19.0	81
CgilhB1	1–3	e1	15	–	83	scl	scl	7.3	7.2	0.42	19.0	81
DmB1	1–3	e1	5	>35	89	c	sc–c	7.3	7.2	0.45	13.2	67
Dg1bB1	1–3	e1	5	>35	89	ls	sc–c	7.3	7.2	0.45	13.2	67
DgibB1st3	1–3	e1	5	>35	89	ls	sc–c	7.3	7.2	0.45	13.2	67
Dg1cC1	3–5	e1	5	>35	89	sl	sc–c	6.4	6.9	0.45	13.2	67
EbB1	1–3	e1	30	15–35	96	gls	gscl	6.4	6.9	0.31	10.1	53
EmB1	1–3	e1	30	15–35	96	gc	gscl	6.4	6.9	0.31	10.1	53
Eg1iB1	1–3	e1	30	15–35	96	gsc	gscl	6.4	6.9	0.31	10.1	53
Eg1cB1St3	1–3	e1	30	15–35	96	gsl	gscl	6.4	6.9	0.31	10.1	53
Eg2cC2St4	3–5	e2	30	15–35	96	gsl	gscl	6.4	6.9	0.31	10.1	53

Eg1hB1–R	1–3	e1	30	15–35	96	gscl	gscl	6.4	6.9	0.28	3.6	53
FbB1	1–3	e1	10	15–35	130	gsc	gsc	6.3	6.6	0.28	3.6	81
FcB1	1–3	e1	10	15–35	130	sl	sc	6.3	6.6	0.28	3.6	81
FhB1	1–3	e1	10	15–35	130	scl	sc	6.3	6.6	0.28	3.6	81
FiB1	1–3	e1	10	15–35	130	sc	gsc	6.3	6.5	0.76	3.6	81
GbB1	1–3	e1	50	15–35	106	gls	gscl	6.2	6.5	0.76	7.0	69
GbB2	1–3	e2	50	15–35	106	gls	gscl	6.2	6.5	0.76	7.0	69
GcB1	1–3	e1	50	15–35	106	gls	gscl	6.2	6.5	0.76	7.0	69
Gg1iC1	3–5	e1	50	15–35	106	gsc	gscl	6.2	6.5	0.76	7.0	69
Gg1hC1St3	3–5	e1	50	15–35; 3–15	106	gscl	gscl	6.2	6.5	0.76	7.0	69
Gg2hC2St3	3–5	e2	50	15–35; 3–15	106	gscl	gscl	6.2	6.5	0.76	7.0	69
Gg1hE3St4	10–15	e3	50	15–35; 15–90	106	gscl	gscl	6.2	6.5	0.76	7.0	69
GbC2St3–R	3–5	e2	50	15–35; 3–15	106	gsl	gscl	6.2	6.5	0.76	7.0	69
Gg2cD2St4–R	5–10	e2	50	15–35; 15–90	106	gsl	gscl	6.2	6.5	0.76	7.0	69
HbB1	1–3	e1	25	>35	144	gls	gsc	5.9	6.3	0.50	6.3	51
HcB1	1–3	e1	25	>35	144	gsl	gsc	5.9	6.3	0.50	6.3	51
HhB1	1–3	e1	25	>35	144	gscl	gsc	5.9	6.3	0.50	6.3	51
Hg1bB1	1–3	e1	25	>35	144	gsl	gsc	5.9	6.3	0.50	6.3	51
Hg2bB1	1–3	e1	25	>35	144	gsl	gsc	5.9	6.3	0.50	6.3	51
Hg1hB1	1–3	e1	25	>35	144	gscl	gsc	5.9	6.3	0.50	6.3	51
Hg1iB1	1–3	e1	25	>35	144	gsc	gsc	5.9	6.3	0.50	6.3	51
Hg1iC1	3–5	e1	25	>35	144	gsc	gsc	5.9	6.3	0.50	6.3	51
Hg2iC1	3–5	e1	25	>35	144	gsc	gsc	5.9	6.3	0.50	6.3	51

... contd

Soil phase	Slope	Erosion	Stoniness/gravelliness		Depth	Texture		pH		Organic C	CEC	Base satn
	(%)		Surface	Subsoil	cm	Surface	Profile	Surface	Profile	(%)	(cmol (+) kg^{-1})	(%)
HcB1St3	1–3	e1	25	>35; 3–15	144	gsl	gsc	5.9	6.3	0.50	6.3	51
Hmc1St3	3–5	e1	25	>35; 3–15	144	gc	gsc	5.9	6.3	0.50	6.3	51
Hg2cD2St3	5–10	e2	25	>35; 3–15	144	gsl	gsc	5.9	6.3	0.50	6.3	51
Hg1cD2St4	5–10	e2	25	>35; 15–90	144	gsl	gsc	5.9	6.3	0.50	6.3	51
Hg1hD2St4	5–10	e2	25	>35; 15–90	144	gscl	gsc	5.9	6.3	0.50	6.3	51
Hg2hD2st4	5–10	e2	25	>35; 15–90	144	gscl	gsc	5.9	6.3	0.50	6.3	51
IcB1	1–3	e1	–	<15	130	sl	scl	6.5	6.4	0.24	6.0	72
IhB1	1–3	e1	–	<15	130	scl	scl	6.5	6.4	0.24	6.0	72
IiB1	1–3	e1	–	<15	130	sc	scl	6.5	6.4	0.24	6.0	72
ImB1	1–3	e1	–	<15	130	c	scl	6.5	6.4	0.24	6.0	72
ImB2	1–3	e2	–	<15	130	c	scl	6.5	6.4	0.24	6.0	72
IbC1	3–5	e1	–	<15	130	ls	scl	6.5	6.4	0.24	6.0	72
IcC1	3–5	e1	–	<15	130	sl	scl	6.5	6.4	0.24	6.0	72
IiC2	3–5	e2	–	<15	130	sc	scl	6.5	6.4	0.24	6.0	72
Ig1hC1	3–5	e1	–	<15	130	scl	scl	6.5	6.4	0.24	6.0	72
Ig2hC2St3	3–5	e2	–	<15; 3–15	130	scl	scl	6.5	6.4	0.24	6.0	72
JhB1	1–3	e1	10	15–35	130	scl	sc	8.3	8.1	0.53	9.4	91
JiB1	1–3	e1	10	15–35	130	sc	sc	8.3	8.1	0.53	9.4	91
Jg1hD2St3	5–10	e2	10	15–35; 3–15	130	scl	sc	9.3	8.1	0.53	9.4	91
KbB1	1–3	e1	10	<15	151	ls	sc	5.9	6.7	0.41	5.5	49
KcB1	1–3	e1	10	<15	151	sl	sc	5.9	6.7	0.41	5.5	49

KhB1	1–3	e1	10	<15	151	scl	sc	5.9	6.7	0.41	5.5	49
KmB1	1–3	e1	10	<15	151	c	sc	5.9	6.7	0.41	5.5	49
KcC1	3–5	e1	10	<15	151	sl	sc	5.9	6.7	0.41	5.5	49
KhC1	3–5	e1	10	<15	151	scl	sc	5.9	6.7	0.41	5.5	49
KiC1	3–5	e1	10	<15	151	sc	sc	5.9	6.7	0.41	5.5	49
KbC2	3–5	e2	10	<15	151	ls	sc	5.9	6.7	0.41	5.5	49
KhD2	5–10	e2	10	<15	151	scl	sc	5.9	6.7	0.41	5.5	49
Kg1cB1	3–5	e1	10	<15	151	sl	sc	5.9	6.7	0.41	5.5	49
Kg1hB1	1–3	e1	10	<15	151	scl	sc	5.9	6.7	0.41	5.5	49
KhD2St3	5–10	e2	10	<15	151	scl	sc	5.9	6.7	0.41	5.5	49
Kg1hC2St4–R	3–5	e2	10	<15	151	scl	sc	6.0	6.7	0.41	5.5	49
Kg2hD2St4–R	5–10	e2	10	>15; 15–90	151	scl	sc	5.9	6.7	0.41	5.5	49
Lg1bC2St3	3–5	e2	15	>35; 3–15	164	ls	scl	6.0	7.7	0.37	7.1	56
Lg1cD2St3	5–10	e2	15	>35; 3–15	164	sl	scl	7.2	7.7	0.37	7.1	56
McB1	1–3	e1	–	–	154	sl	scl	7.2	8.0	0.53	7.7	99
MhB1	1–3	e1	–	–	154	scl	scl	7.5	8.0	0.53	7.7	99
NbB1	1–3	e1	–	–	150	ls	sl	7.5	8.0	0.43	12.3	57
NcB1	1–3	e1	–	–	150	sl	sl	7.5	8.0	0.43	12.3	57
NhB1	1–3	e1	–	–	150	scl	sl	7.5	8.0	0.43	12.3	57
NiB1	1–3	e1	–	–	150	sc	sl	7.5	8.0	0.43	12.3	57



a b

Fig. 2.4 Profiles of (a) soil series A and (b) soil series B, Garakahalli watershed.

a

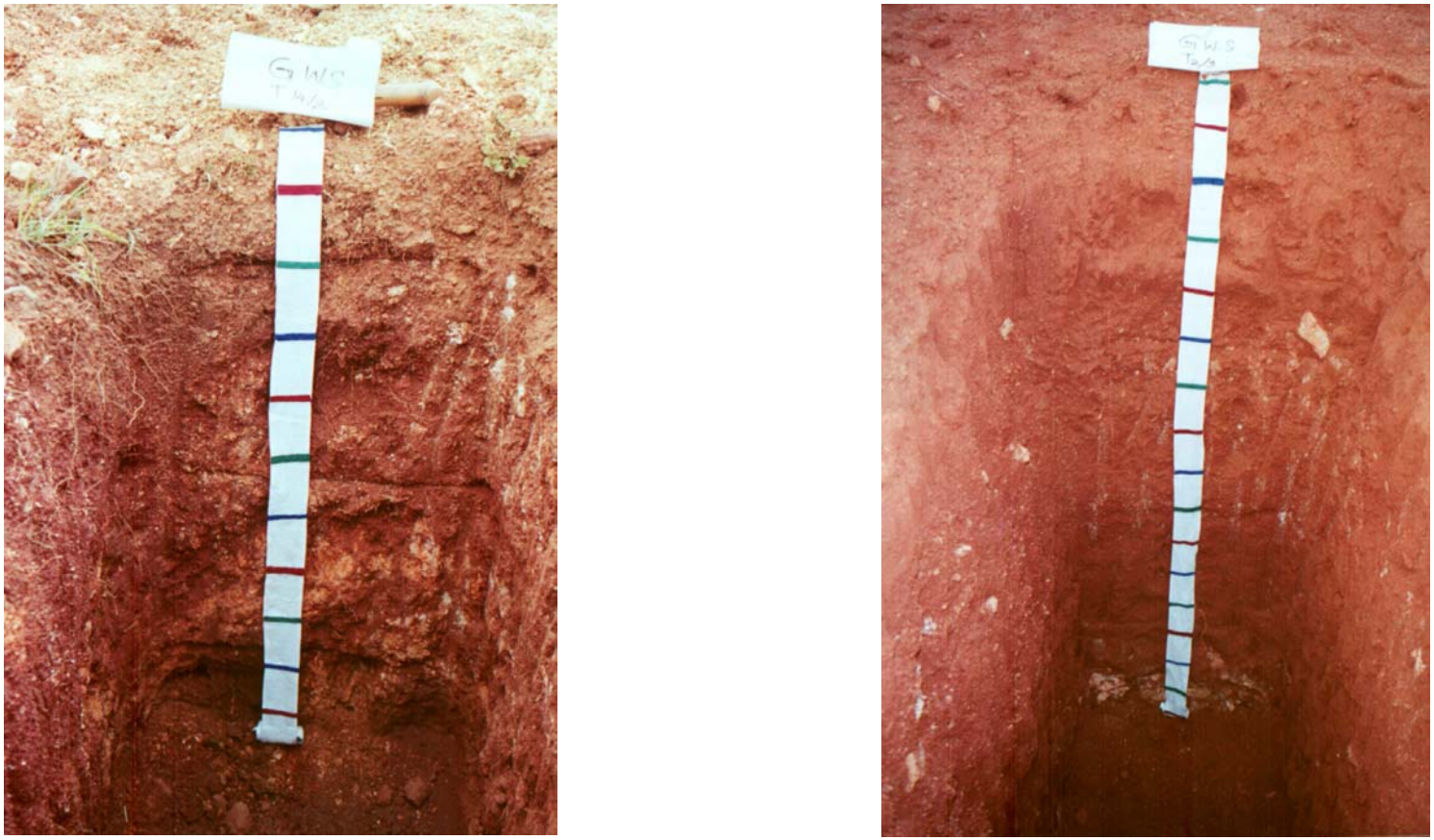
b

Fig. 2.5 Profiles of (a) soil series C and (b) soil series D, Garakahalli watershed.

a

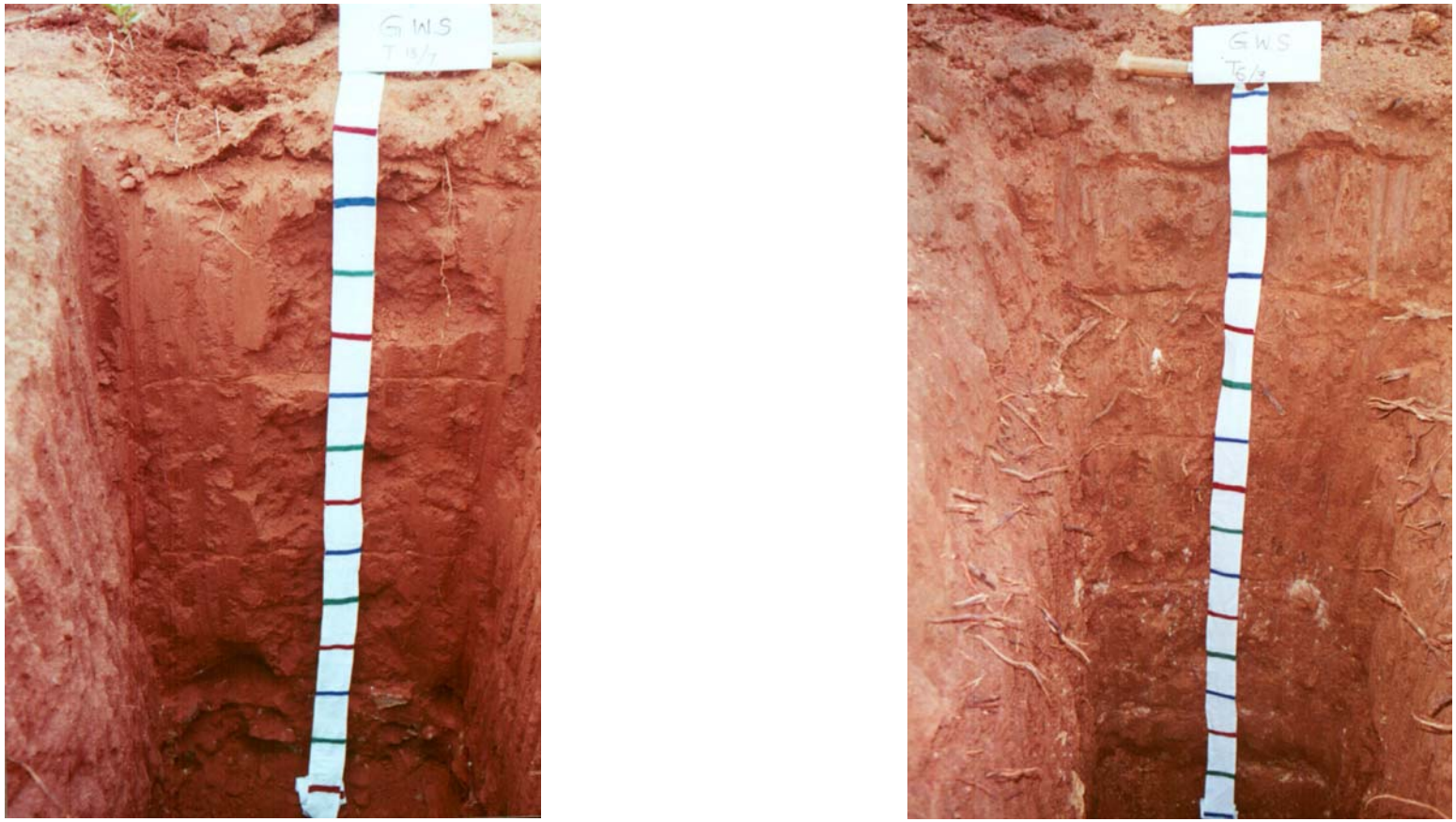
b

Fig. 2.6 Profiles of (a) soil series E and (b) soil series F, Garakahalli watershed.



a b

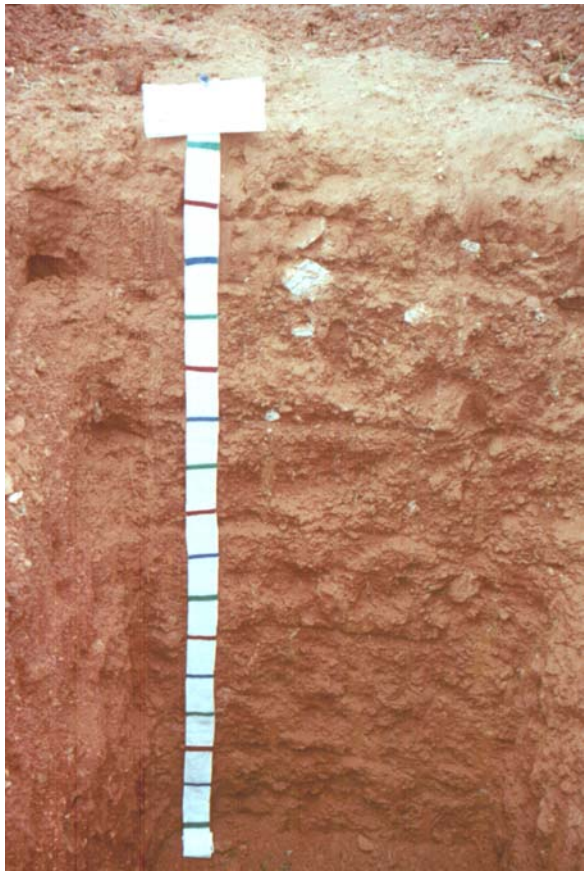
Fig. 2.7 Profiles of (a) soil series G and (b) soil series H, Garakahalli watershed.



a b

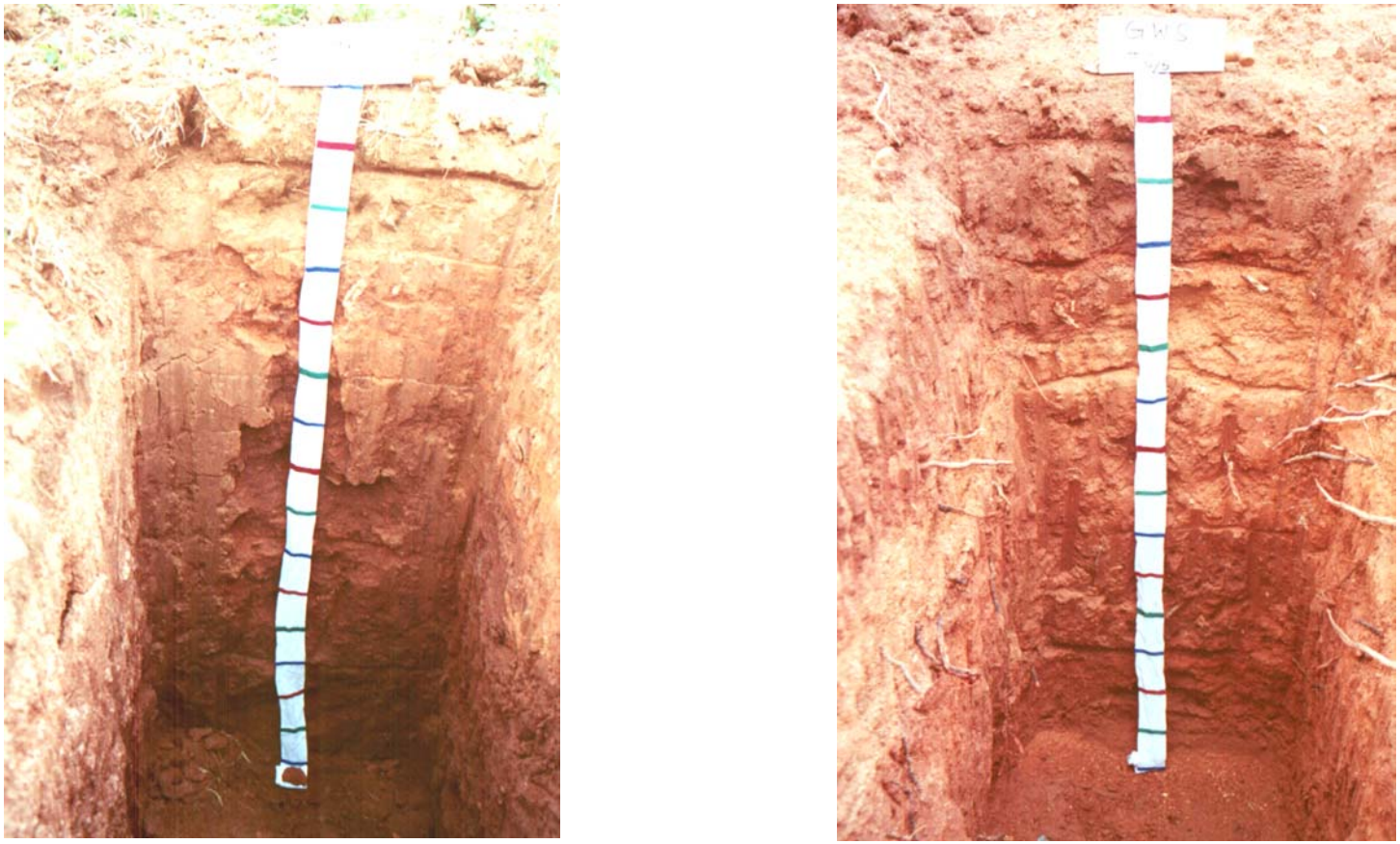
Fig. 2.8 Profiles of (a) soil series I and (b) soil series J, Garakahalli watershed.

a



b

Fig. 2.9 Profiles of (a) soil series K and (b) soil series L, Garakahalli watershed.



a b

Fig. 2.10 Profiles of (a) soil series M and (b) soil series N, Garakahalli watershed.

3. SOCIO-ECONOMIC CHARACTERISTICS OF FARM HOUSEHOLDS

3.1 General Features

The total geographical area of Garakahalli microwatershed is 527 hectares. The culti-vable area was 438.58 ha, of which only 307 ha were cultivated, about 223 ha under rainfed and 84 ha under irrigated conditions (Table 3.1). Common property lands accounted for 166 ha, and roads and habitation constituted 11.5 ha and water bodies 45 ha. The number of households in the water-shed was 251, of which 164 were marginal farmers, 68 small and 19 large farmers. The total human population was 1454 and livestock population 927.

Table 3.1 General features of Garakahalli watershed

Item	Unit	Value
Total geographical area of the watershed	ha	527.21
Total cultivable area	ha	306.65
Rainfed	ha	222.96
Irrigated	ha	83.69
Common property land	ha	165.79
Roads and habitation	ha	11.50
Water bodies	ha	44.91
Households		
Marginal farmers (<1 ha)	number	164
Small farmers (1–2 ha)	number	68
Large farmers (>2 ha)	number	19
Total human population	number	1454
Total livestock	number	927

3.2 Demographic Issues

The data presented in Table 3.2 show that around 60 per cent of the total farmers were middle aged, 36 per cent were old and only 4.38 per cent were young. Among marginal farmers 57 per cent were middle aged, 38 per cent were old aged and 5 per cent were young, while 62 per cent of small farmers were middle aged to 34 per cent were old and 4.4 per cent were young. In case of large farmers there were no young farmers, 74 per cent were middle aged and 26 per cent were old.

With regard to educational status, 69 per cent of the farmers were illiterate, 9 per cent were primary school literate, 10 per cent secondary school literate, 8 per cent high school literate and 4 per cent college literate. Among marginal farmers 73 per cent were illiterate, 7 per cent each were primary and high school literate, 10 per cent were secondary school literate and 3 per cent were college literate. In small farmers, 69 per cent were illiterate 7 per cent were primary school literate, 9 per cent each were secondary and high school literate and per cent were college literate. Among large farmers 42 per cent were illiterate, 26 per cent primary school literate, 16 per cent secondary school literate, 11 per cent high school literate and 5 per cent college literate.

Table 3.2 Demographic characteristics of farm households in Garakahalli watershed

Particulars	Marginal farmers		Small farmers		Large farmers		Pooled farmers	
	Num.	%	Num.	%	Num.	%	Num.	%
Total number of households	164	65.34	68	27.09	19	7.57	251	100
Age (years)								
Young (<30)	8	4.88	3	4.41	–	–	11	4.38
Middle–aged (30 to 50)	94	57.32	42	61.76	14	73.68	150	59.76
Old (>50)	62	37.80	23	33.82	5	26.32	90	35.86
Total	164	100	68	100	19	100	251	100
Family size (members)								
Small (<5)	80	48.78	26	38.24	9	47.37	115	45.82
Medium (5 to 10)	71	43.29	34	50.00	8	42.11	113	45.02
Large (>10)	13	7.93	8	11.76	2	10.53	23	9.16
Total	164	100	68	100	19	100	251	100
Educational status								
Illiterate	119	72.56	47	69.12	8	42.11	174	69.32
Primary school	12	7.32	5	7.35	5	26.32	22	8.76
Secondary school	16	9.76	6	8.82	3	15.79	25	9.96
High school	12	7.32	6	8.82	2	10.53	20	7.97
College	5	3.05	4	5.88	1	5.26	10	3.98
Total	164	100	68	100	19	100	251	100
Institutional membership								
Panchayat	2	1.22	3	4.41	1	5.26	6	2.39
Cooperative Society	17	10.37	16	23.53	5	26.32	38	15.14
Non–government org.	–	–	–	–	–	–	–	–
Taluk development board	–	–	–	–	–	–	–	–
Youth club	–	–	–	–	–	–	–	–
Non–members	145	88.41	49	72.06	13	68.42	207	82.47
Total	164	100	68	100	19	100	251	100
Social groups								
Scheduled Caste	5	3.05	–	–	–	–	5	1.99
Scheduled Tribe	6	3.66	–	–	–	–	6	2.39
Other Backward Classes	150	91.46	68	100	19	100	237	94.42
General	3	1.83	–	–	–	–	3	1.20
Total	1640	1000	68	100	19.00	100	251	100

Among marginal farmers, 80 households (49%) had <5 members, 71 families were medium sized (43%) and 13 households large sized (8%). Among small farmers, 26 families were small (38%), 34 and 8 households were medium (50%) and large size (12%), respectively. Among the large farm households 9 (47%) had small families, 8 (42%) medium families and 2 (11%) had large families.

Among the pooled households 46 per cent had small families, 45 per cent medium and 9 per cent large families.

Hardly 15 per cent of the farmers were members of cooperative society and 2 per cent were members of the panchayat.

All the large and small farmers belonged to Other Backward Classes, while among the marginal farmers about 2 per cent belonged to general category, 91.5 per cent to Other Backward Classes, 3 per cent to Scheduled Castes and 3.7 per cent to Scheduled Tribes.

Family size and composition (Table 3.3). The average family size in the watershed was 5.79, with 3.63 working population (1.97 male, 1.66 female) and 1.97 dependent children. Among marginal farmers, the average family size was 5.63, with on average 1.86 male and 1.62 female working population and 1.94 dependent children. The average family size of small farmers was 6.07 consisting of 2.19 male and 1.69 female working population, 2.06 dependent children. On the other hand, the average family size of large farmers was 6.16 with 2.16 male and 1.89 female working population and 1.75 dependent children. Thus large-farmer families had more working population and hence were economically sound.

Table 3.3 Family size and composition among Garakahalli farm households

Item	Marginal farmers	Small farmers	Large farmers	Pooled farmers
Average family size	5.63	6.07	6.16	5.79
Average working population				
Male	1.86	2.19	2.16	1.97
Female	1.62	1.69	1.89	1.66
Total	3.48	3.88	4.05	3.63
Dependents				
Children	1.94	2.06	1.95	1.97

Farm household occupational pattern (Table 3.4). The occupational pattern of the farm house-holds in the watershed as a whole showed that 113 farm households (45%) depended on crop production as main occupation and sericulture as subsidiary occupation, followed by 18 per cent (46) dependent on crop production and dairy enterprise, 14 per cent dependent on crop produc-tion

and agricultural labour, and 12.7 per cent dependent on agricultural labour and crop produc-tion as main and subsidiary occupation respectively. Crop production was main occupation and sheep/goat rearing subsidiary occupation for 6 per cent of the farm households. Only 1.59 per cent were in Government service and had crop production as subsidiary occupation

Approximately the same general pattern was noted among the three size groups, except that agricultural labour was main occupation for some marginal farmers but not for small or large farmers. About 10 per cent of small farmers had agricultural labour as subsidiary occupation.

Genderwise occupation pattern (Table 3.5). Considering the watershed as a whole, the adult male:female ratio was 1.24 and the children:adult female ratio 1.16.

Among marginal farmers, out of 924 population, 336 were males, 270 were females (M:F ratio 1.24) and 318 were children. Among males, 275 were engaged in farming, 23 worked as agricultural labour, 2 were government employees, 5 were doing business, 2 were studying and 31 were non-working. On the other hand, out of 278 females 255 were engaged in farming, 10 engaged as agricultural labour, 1 was a Government employee and only 4 were non-working. Out of 318 children, 194 were studying.

Small farmers constituted 413 of the total population, with 152 males, 121 females and 140 children. Of the males, 145 were engaged in farming, 2 were businessmen, 2 were studying and 3 were non-working. Among females 113 were engaged in farming, one worked as agricul-tural labour, 2 were salaried and 6 non-working. Of the total children, 92 were studying.

Considering 117 large farmers, 48 were males, 37 were females and 37 were children. Among the males, 39 were engaged in farming, 2 were doing business and 2 were non-working. Among the females, 36 were farming and 1 was non-working. Of 37 children, 25 were studying.

Table 3.5 Genderwise occupation pattern in farm families in Garakahalli watershed

Particulars	Marginal farmers		Small farmers		Large farmers		Pooled	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Total male	336	36.36	152	36.80	43	36.75	531	36.52
Farming	275	29.76	145	35.11	39	33.33	459	31.57
Agric. labour	23	2.49	0	0.00	0	0.00	23	1.58
Salaried	2	0.22	0	0.00	0	0.00	2	0.14
Business/trade	3	0.32	2	0.48	1	0.85	6	0.41
Studying	2	0.22	2	0.48	0	0.00	4	0.28
Non-working	31	3.35	3	0.73	2	1.71	36	2.48
Total female	270	29.22	121	29.30	37	31.62	428	29.44
Farming	255	27.60	113	27.36	36	30.77	404	27.79
Agric. labour	10	1.08	1	0.24	0	0.00	11	0.76
Salaried	1	0.11	2	0.48	0	0.00	3	0.21
Business/trade	0	0.00	0	0.00	0	0.00	0	0.00
Studying	0	0.00	0	0.00	0	0.00	0	0.00
Non-working	4	0.43	6	1.45	1	0.85	11	0.76
Total children	318	34.42	140	33.90	37	31.62	495	34.04
Studying	194	21.00	92	22.28	25	21.37	311	21.39
Not studying	124	13.42	48	11.62	12	10.26	184	12.65
Total population	924	100.00	413	100.00	117	100.00	1454	100.00

Average annual household income (Table 3.6). The average annual household income from different sources varied among the three categories of farmers. Average annual income among marginal farmers (Rs 32232.90) was lowest compared to that of small (Rs 49537.13) and large farmers (Rs 52395.78).

Income from sericulture formed 40.85, 46.29 and 38.37 per cent, with crop production accounting for 31.5, 36.94 and 44.38 per cent respectively among marginal, small and large farmers, respectively. Dairy enterprise contributed Rs 3425.63, Rs 2980.56 and Rs 2550.65 and sheep and goat rearing contributed Rs 1575.45, Rs 1350.42 and Rs 1425.5 respectively among marginal, small and large farmers. Income from business was Rs 1250.00, Rs 3975.50 and Rs 4585.70 among marginal, small and large farmers respectively. Only marginal farmers had income from agricultural labour (Rs 1350.65) and rural artisanship (Rs 455.85), while both marginal (Rs 850.00) and large farmers (Rs 475.60) had income from Government service (2.61% and 0.9%, respectively, of the total income).

Distribution of land holdings (Table 3.7). The total cultivated area in the watershed was 306.65 ha, of which 220.92 ha was owned rainfed land (72.04%), 83.04 ha owned irrigated land (27.08%), 2.04 ha leased-in rainfed land (0.67%) and 0.65 ha leased-in irrigated land (0.21%).

Considering the landholding of marginal farmers, around 78.54 ha (73.88%) was owned rainfed land, 27.16 ha (25.55%) owned irrigated land, 0.2 ha (0.19%) leased-in rainfed land and 0.4 ha (0.38%) leased-in irrigated land. Among small farmers, owned rainfed land was 95.44 ha (74.98%), owned irrigated land 29.76 ha (23.38%), leased-in rainfed land 1.84 ha (1.45%) and leased-in irrigated land 0.25 ha (0.2%). Large farmers had no leased-in land, and the owned rainfed area was 46.94 ha (64.25%) and owned irrigated land accounted for 26.12 ha (48%).

Livestock population among farm households (Table 3.8). The total livestock population in Garakahalli was 927, of which 46 (5%) were bullocks, 212 (23%) dual-purpose cows, 69 (7%) crossbred cows, 110 (12%) buffaloes, 26 (3%) poultry birds, 282 (30%) sheep and 182 (20%) goats.

The number of bullocks was 18, 20 and 8 among marginal, small and large farmers, res-pectively. Dual purpose cows were 140, 60 and 12 among marginal, small and large farmers, respectively, crossbred cows 35, 25 and 9, while number of buffaloes was 64, 33 and 13, respec-tively, among marginal farmers, small farmers and large farmers. The number of poultry birds was 10 and 16 among marginal and small farmers; large farmers did not possess any poultry birds. Number of sheep was 200, 65 and 17 among marginal, small and large farmers, respec-tively, and the number of goats among marginal (104), small (64) and large farmers (14) respec-tively accounted for 18, 23 and 19 per cent of the total livestock population. Marginal farmers (571) owned highest livestock population followed by small (283) and large farmers (73).

Population pressure (Table 3.9). The density of human population per hectare was 4.74 and that of animals was 0.6. The average size of holding was 1.22 ha among the pooled farmers in the watershed area. Marginal farmers had a density of human population of 8.69/ha and of ani-mal population of 0.6/ha. The

average size of land holding was 0.65 ha and availability of land per person was 0.12 ha and per animal 0.19 ha. On the other hand, the density of human and animal population among small farmers was 3.24 and 0.64 per ha respectively and average size of land holding was 1.87 ha. The land available was 0.31 ha per person and 0.45 ha per animal.

Considering large farmers, the density of humans was 1.6 per ha and that of animals was 0.51 per ha. However, the average size of land holding was greater among large farmers at 3.85 ha and the available per person was 0.62 ha and per animal 1 ha.

Tenurial status (Table 3.10). In Garakahalli watershed, 202 farmers had land records in their names, and the perceived reasons for possession of land records were security (166), prestige (23), self-satisfaction (72) and for bank loan (25). However, 49 farmers did not possess land records in their names and the reasons quoted were family dispute (40), litigation (6) and high cost of registration.

Among the marginal, small and marginal farmers, respectively 129 (79%), 58 (85%) and 15 (59%) had land records in their names. The reasons quoted for having land records were security (113, 46 and 7 marginal, small and large farmers), prestige (11, 4 and 8 marginal, small and large farmers), self satisfaction (44, 24 and 4 marginal, small and large farmers) and for bank loan (11, 11 and 3 marginal, small and large farmers). However, 35 marginal, 10 small and 4 large farmers did not have land records in their names and the major reasons reported were family dispute (28 marginal, 8 small and 4 large farmers), litigation (3 marginal, 1 small and 2 large farmers) and high cost of registration (4 marginal farmers).

Table 3.9 Population pressure in Garakahalli watershed

Number of farm households	Marginal farmers	Small farmers	Large farmers	Pooled farmers
	164	68	19	251
Cultivable land, ha				
Rainfed	78.74	97.28	46.94	222.96
Irrigated	27.56	30.01	26.12	83.69
Total population				
Human	924	413	117	1454
Animal	571	283	73	927
Density, number/ha				
Human	8.69	3.24	1.60	4.74
Animal	0.60	0.64	0.51	0.60
Average size of land holding, ha	0.65	1.87	3.85	1.22
Cultivable land available, ha				
Per person	0.12	0.31	0.62	0.21
Per animal	0.19	0.45	1.00	0.33

Marginal, small and large farmers had 78.74, 97.28 and 46.92 ha, respectively, under rainfed agriculture and 27.56, 30.01 and 26.12 ha, respectively, under irrigation. The crops grown on rainfed land were finger millet (61.44, 59.68 and 24.1 ha, respectively), groundnut (7.18, 16.9 and 12.92 ha, respectively), coconut (2.27, 4.56 and 2.5 ha, respectively), and horse-gram (6.09, 12.19 and 4.35 ha, respectively). On irrigated lands, banana was grown on 2.74, 6.0 and 8.8 ha, coconut plantations covered 7.03, 6.03 and 6.05 ha and mulberry was grown on 9.56, 9.22 and 3.34 ha respectively by marginal, small and large farmers. However, only large farmers had mango orchards to an extent of 1.4 ha and only small farmers cultivated sugarcane and ground-nut on 0.4 ha each. The land left fallow was 1.75, 3.95 and 3.05 ha rainfed land and 1.91, 1.28 and 1.73 ha irrigated land among marginal, small and large farmers, respectively.

Cropping pattern (Table 3.11). Out of the total cultivated land 222.94 ha (72.71%) was rainfed and 83.69 ha (27.29%) was irrigated land. In rainfed land 145.22 ha was under finger millet, followed by groundnut (37 ha), horsegram (22.63 ha) and coconut (9.33 ha). Under irrigated condition, 22.12 ha (26.4%) was under mulberry, 19.11 ha (23%) under coconut, 17.54 ha (21%) under banana, 7.45 ha (9%) under rice, 10.34 ha (12%) under finger millet, 1.4 ha (2%) under mango, 0.4 ha (0.48%) under sugarcane and 0.4 ha under groundnut.

3.3 Assessment of Impact of the Watershed Programme

Component-wise investment under NWDPRA. The total amount spent under NWDPRA in Garakahalli watershed was Rs 16,31,940.00 (Table 3.12), of which Rs 7,25,760.00 (48.76%) was spent on soil- and water-conservation measures, Rs 4,69,180.00 (28.75) on basic activities such as projectization, identification of the area, survey and so on, Rs 80.000.00 (4.90%) on crop demonstration and Rs 1,86,000.00 on household production system. The amount spent on live-stock development (Rs 26,000), horticulture development (Rs 40,000.00) and agroforestry (Rs 35,000.00) together accounted for 6.18 per cent of the total investment.

Table 3.11 Cropping pattern (area) among farmers in Garakahalli watershed

Crops grown	Marginal farmers		Small farmers		Large farmers		Pooled farmers	
	ha	%	ha	%	ha	%	ha	%
Rainfed								
Coconut	2.27	2.89	4.56	4.68	2.5	5.33	9.33	4.18
Groundnut	7.18	9.12	16.90	17.38	12.92	27.54	37	16.60
Finger millet	61.44	78.04	59.68	61.35	24.1	51.36	145.22	65.14
Horsegram	6.09	7.74	12.19	12.53	4.348	9.27	22.63	10.15
Fallow	1.75	2.22	3.95	4.06	3.052	6.50	8.75	3.92
Total	78.74	100	97.28	100	46.92	100	222.94	100
Irrigated								
Banana	2.74	9.94	6	19.99	8.8	33.69	17.54	20.96
Coconut	7.03	25.51	6.03	20.09	6.052	23.17	19.11	22.84
Mulberry	9.56	34.70	9.22	30.72	3.34	12.79	22.12	26.44
Rice	1.96	7.11	3.10	10.33	2.39	9.15	7.45	8.90
Finger millet	4.35	15.79	3.58	11.93	2.41	9.23	10.34	12.36
Mango	0	0	0	0	1.40	5.36	1.40	1.67
Sugarcane	0	0	0.40	1.33	0	0	0.40	0.48
Groundnut	0	0	0.40	1.33	0	0	0.40	0.48
Fallow	1.91	6.94	1.28	4.27	1.73	6.62	4.92	5.88
Total	27.56	100	30.01	100	26.12	100	83.69	100

Table 3.12 Componentwise investment in Garakahalli watershed under NWDPRA

Component	Amount invested	
	Rs	%
Basic activities	469180.00	28.75
Soil and water conservation measures	795760.00	48.76
Crop demonstration	80000.00	4.90
Household production system	186000.00	11.40
Livestock development	26000.00	1.59
Horticulture	40000.00	2.45
Agroforestry	35000.00	2.14
Total	1631940.00	100.00

Beneficiaries under various components of watershed development. Beneficiaries under different components of watershed are given in Table 3.13. Among the farmers, 43 marginal, 29 small and 8 large farmers benefited from soil- and water-conservation measures, 4, 3 and 4 from crop demonstration, 6, 5 and 2 from household production system, 24, 15 and 3 from live-stock development, 74, 39 and 13 from agroforestry and 8, 7 and 5, from horticulture development, respectively . The farmers who did not derive any benefit were 33 small, 11 small and 4 large.

Impact on land use pattern (Table 3.14). There was no change in owned rainfed (220.92 ha) and irrigated (83.04 ha) land, but there was an increase in leased-in land by 1.2 ha of rainfed and 0.45 ha of irrigated land after development. The change in land value negligible. Among marginal farmers, owned cultivable land stayed at 78.54 ha rainfed and 27.16 ha irrigated; however there was increase in land value by Rs. 600/ha (owned rainfed) and Rs. 3750/ha (leased-in irrigated).

Table 3.13 Beneficiaries under the components of watershed development in Garakahalli watershed

Component	Marginal farmers		Small farmers		Large farmers		Pooled farmers	
	Num.	%	Num.	%	Num.	%	Num.	%
Soil cons. measures	43	26.22	29	42.65	8	42.11	80	31.87
Crop demonstration	4	2.44	3	4.41	4	21.05	11	4.38
Household production system	6	3.66	5	7.35	2	10.53	13	5.18
Livestock development	24	14.63	15	22.06	3	15.79	42	16.73
Horticulture	8	4.88	7	10.29	5	26.32	20	7.97
Agroforestry	74	45.12	39	57.35	13	68.42	126	50.20
Not benefited	33	20.12	11	16.18	4	21.05	48	19.12

Table 3.14 Impact of watershed development on land-use pattern in Garakahalli watershed

Particulars	Before development		After development		Change	
	Area (ha)	Av. value (Rs/ha)	Area (ha)	Av. value (Rs/ha)	Area (ha)	Av. value (Rs/ha)
Marginal farmers						
Owned cultivable land						
Rainfed	78.54	83400.00	78.54	84000.00	0.00	600.00
Irrigated	27.16	142700.00	27.16	142700.00	0.00	0.00
Leased-in land						
Rainfed	0.20	88950.00	0.20	88950.00	0.00	0.00
Irrigated	0.1	146250.00	0.40	150000.00	0.30	3750.00
Small farmers						
Owned cultivable land						
Rainfed	95.44	85400.00	95.44	87707.50	0.00	2307.50
Irrigated	29.76	149100.00	29.76	151125.00	0.00	2025.00
Leased-in land						
Rainfed	0.64	90000.00	1.84	90000.00	1.20	0.00
Irrigated	0.1	149950.00	0.25	151937.50	0.15	1987.50
Large farmers						
Owned cultivable land						
Rainfed	46.944	84000.00	46.944	84000.00	0.00	0.00
Irrigated	26.12	149100.00	26.12	149100.00	0.00	0.00
Leased-in land						
Rainfed	0.00	0.00	0.00	0.00	0.00	0.00
Irrigated	0.00	0.00	0.00	0.00	0.00	0.00
Pooled farmers						
Owned cultivable land						
Rainfed	220.92	84266.67	220.92	85235.83	0.00	969.17
Irrigated	83.04	146966.67	83.04	147641.67	0.00	675.00
Leased-in land						
Rainfed	0.84	89475.00	2.04	89475.00	1.20	0.00
Irrigated	0.20	148100.00	0.65	150968.75	0.45	2868.75

The land holding of small farmers was 95.44 ha owned rainfed and 29.76 ha owned irrigated land before and after implementation of the project. There was an increase in the value of land after implementation of the project from Rs. 85400/ha to Rs. 87707.50/ha of rainfed land and Rs. 149100/ha to 151125/ha of irrigated land. The area of leased-in rainfed land increased from 0.64 ha to 1.84 ha valued at Rs.90000/ha and that of leased-in irrigated land from 0.1 to 0.25 ha with increase in land value from Rs. 149950/ha to Rs. 151937.5/ha consequent on imple-mentation of the project. There was no change following watershed development in area of land held or value of the land in the case of large farmers.

Impact on cropping pattern. Cropping pattern adopted by marginal farmers before and after watershed development is presented in Table 3.15. Of the rainfed land, the area under coconut increased from 2.27 ha to 2.67 ha, under finger millet in *kharif* increased from 58.44 ha to 61.44 ha, but the area under groundnut stayed unchanged at 7.18 ha and that under horsegram decreased from 7.29 ha to 6.09 ha. Under irrigation, increases were seen in banana, mulberry, rice and finger millet. There was a decrease in fallow area in both rainfed and irrigated lands.

Among small farmers (Table 3.16), in rainfed cultivation, the area under coconut was unchanged, while that under groundnut increased from 14.20 ha to 16.90 ha, that under finger millet from 55.40 ha to 59.68 ha following watershed development. However, area under horse-gram decreased from 14.36 ha to 12.19 ha and that under fallow from 7.56 ha to 3.95 ha. Under irrigated conditions, areas under banana, coconut, mulberry and finger millet increased perceptibly, while that under rice and sugarcane showed spectacular increase in terms of percentage. There was significant decrease in fallow area following watershed development.

The cropping pattern adopted by large farmers is given in Table 3.17. Increase in area under specific crops on rainfed land following development was seen in coconut, groundnut and finger millet. There was significant decrease in land under horsegram and the land left fallow. Under irrigated conditions, increases were seen in all crops except mango; the largest increase was in mulberry and banana, and in the *kharif* field crops rice and finger millet. The decrease in fallow land following watershed development was >55 per cent in *kharif* and >30 per cent in *rabi*.

The overall picture for the farmers when pooled is given in Table 3.18. In rainfed agri-culture, the area under coconut increased by nearly 8 per cent, under groundnut by 20 per cent, under finger millet 8 per cent. Area under horsegram and fallow decreased by >24 and >50 per cent, respectively. In the case of irrigated land, area under banana increased by >13 per cent and under mulberry by >7 per cent. Area under the irrigated field crop rice increased by 18 per cent in *kharif* and 21 per cent in *rabi* as a consequence of watershed development.

Impact on livestock population. Among marginal (Table 3.19), small (Table 3.20) and large farmers (Table 3.21), the number of households having livestock were 120, 58 and 16 before and 120, 59 and 16 after development. Increase in livestock among marginal (571 to 823), small (283 to 398) and large farmers (73 to 111) was due to increase in dual-purpose cows (4, 8 and 4), crossbred cows (4, 8 and 4), buffaloes (4, 8 and 4), poultry (23, 2 and 0), sheep (120, 40 and 13) and goats (85, 44 and 10). Around half the farm households in the watershed did not own bullocks. The improvement on development was small both numerically and in terms of value.

In Garakahalli watershed as a whole, the impact of the watershed development prog-ramme on livestock was seen through increase in total animals from 927 to 1332 (Table 3.22) with marginal increase in their value. The number of households having at least one type of live-stock was 195. The increase in number of dual-purpose cows was 16, of crossbred cows 15, of buffaloes 37, of sheep 173 and of goats 139. There was no change in the number of bullocks.

Impact on agro-biodiversity. Prior to watershed development, marginal, small and large far-mers had respectively 9, 5 and 4 kinds of trees on their land, which changed after development to 14, 6 and 7 kinds (Table 3.23). The tree species exclusive to marginal farmers and increases in their numbers were acacia (5), *baghe* (5), *bersy* (9), eucalyptus (9), neem (4), pomegranate (4), silver oak (77) and sapota (8). Increases were seen among marginal, small and large farmers in coconut (439, 64 and 36), mango (918, 152 and 41), pongamia (16, 20 and 3) and teak trees (365, 38 and 29). Increase in jack was 6 in marginal and large farmers and tamarind also 6 each in marginal and small farmers.

Impact on average annual household income. The gross annual income from different sources per household of marginal farmers (Table 3.24) was Rs.30582.61 before and Rs.32232.92 after watershed development. Income from sericulture formed the largest proportion of the total followed by incomes from crop production, dairy enterprise, sheep and goat rearing, agricultural labour and business.

Among small farmers, the annual gross income per household was Rs. 47385.75 and Rs. 49537.13, respectively, before and after watershed development (Table 3.25). The major source of income was sericulture, followed by crop production, dairy enterprise, business and sheep and goat rearing. More than one-third of the increase in income was from business. The next lower contributor to the increase was dairy enterprise.

The annual gross income per large-farmer household was Rs 49784.85 and Rs 52395.78 before and after watershed development, respectively (Table 3.26). Crop production formed the major source of income followed by sericulture, and business. More than 84 per cent of the increase in annual income came from business. Large farmers had no income from agricultural labour or rural artisanship.

When the pooled farmers were considered (Table 3.27), the gross annual income per household was Rs 42584.4 before and Rs 44569.99 after watershed development. More than 46 per cent of the increase came from business. Dairy enterprise contributed 7.19, sheep and goat rearing 2.96, sericulture 2.06 and crop production 1.97 per cent of the total increase.

Impact on value of farm assets. The average value of farm assets among the three groups of farmers did not significantly change following watershed development. The average value per hectare rainfed land prior to watershed development was Rs. 83400, Rs 85400 and Rs 84000 among marginal, small and large farmers, respectively, and increased to Rs. 84000, Rs 87707 and Rs 84000 after development. The value of irrigated land remained the same at Rs 142700 and Rs.149100 among marginal and large farmers, respectively, while among small farmers the value increased marginally from 149100 to 151125.

Table 3.24 Change in annual household income among marginal farmers as a result of development in Garakahalli watershed

Source of income	Before development		After development		Change	
	Income (Rs)	%	Income (Rs)	%	Income (Rs)	%
Crop production	9757.79	31.91	10159.48	31.52	401.69	–0.39
Agricultural labour	1350.65	4.42	1350.65	4.19	0.00	–0.23
Sheep/goat rearing	1450.54	4.74	1575.45	4.89	124.91	0.14
Dairy enterprise	3250.65	10.63	3425.63	10.63	174.98	0.00
Sericulture	12672.98	41.44	13165.86	40.85	492.88	–0.59
Business	1250.00	4.09	1250.00	3.88	0.00	–0.21
Govt. service	850.00	2.78	850.00	2.64	0.00	–0.14
Rural artisanship	455.85	1.49	455.85	1.41	0.00	–0.08
Total	30582.61	100.00	32232.92	100.00	1650.31	0.00

Table 3.25 Change in annual household income among small farmers as a result of development in Garakahalli watershed

Source of income	Before development		After development		Change	
	Income (Rs)	%	Income (Rs)	%	Income (Rs)	%
Crop production	17969.83	37.92	18299.83	36.94	330.00	–0.98
Agricultural labour	0.00	0.00	0.00	0.00	0.00	0.00
Sheep/goat rearing	1350.42	2.85	1350.42	2.73	0.00	–0.12
Dairy enterprise	2554.52	5.39	2980.56	6.02	426.04	–0.63
Sericulture	22535.98	47.56	22930.82	46.29	394.84	–1.27
Business	2975.00	6.28	3975.50	8.03	1000.50	1.75
Govt. service	0.00	0.00	0.00	0.00	0.00	0.00
Rural artisanship	0.00	0.00	0.00	0.00	0.00	0.00
Total	47385.75	100.00	49537.13	100.00	2151.38	0.00

Table 3.26 Change in annual household income among large farmers as a result of development in Garakahalli watershed

Source of income	Before development		After development		Change	
	Income (Rs)	%	Income (Rs)	%	Income (Rs)	%
Crop production	22988.75	46.18	23253.98	44.38	265.23	–1.79
Agricultural labour	0.00	0.00	0.00	0.00	0.00	0.00
Sheep/goat rearing	1425.50	2.86	1425.50	2.72	0.00	–0.14
Dairy enterprise	2550.65	5.12	2550.65	4.87	0.00	–0.26
Sericulture	19858.65	39.89	20104.35	38.37	245.70	–1.52
Business	2485.70	4.99	4585.70	8.75	2100.00	3.76
Govt. service	475.60	0.96	475.60	0.91	0.00	–0.05
Rural artisanship	0.00	0.00	0.00	0.00	0.00	0.00
Total	49784.85	100.00	52395.78	100.00	2610.93	0.00

Table 3.27 Change in annual household income among pooled farmers as a result of development in Garakahalli watershed

Source of income	Before development		After development		Change	
	Income (Rs)	%	Income (Rs)	%	Income (Rs)	%
Crop production	16905.46	39.70	17237.76	38.68	332.31	–1.02
Agricultural labour	450.22	1.06	450.22	1.01	0.00	–0.05
Sheep/goat rearing	1408.82	3.31	1450.46	3.25	41.64	–0.05
Dairy enterprise	2785.27	6.54	2985.61	6.70	200.34	0.16
Sericulture	18355.87	43.10	18733.68	42.03	377.81	–1.07
Business	2236.90	5.25	3270.40	7.34	1033.50	2.08
Govt. service	441.87	1.04	441.87	0.99	0.00	–0.05
Rural artisanship	151.95	0.36	151.95	0.34	0.00	–0.02
Total	42584.40	100.00	44569.99	100.00	1985.59	0.00

The average value of livestock of 120 marginal (Table 3.28), 50 small (Table 3.29) and 16 large farmers (Table 3.30) was Rs. 3740.07, Rs.3684.14 and Rs.3749.57, respectively, before development and increased to Rs. 3796.21, Rs.3788.71 and Rs.3826.14, respectively, after development. There was no change in value of dwelling house in all three groups. The number of cattlesheds increased from none to 2 among marginal farmers and from 6 to 8 among large farmers. Tubewells and pumpsets were assets of 33 marginal, 16 small and 9 large farmers before development cost Rs.46497, Rs.46500 and Rs.50417, respectively. The number increased by one each in small and large farmers, and the value became Rs. 48721, Rs. 46667 and Rs.50417 for marginal, small and large farmers, respectively, after development. There was no change in value of bullock cart before and after implementation of the project valued at Rs.11333, Rs.8200 and Rs.12000 among marginal, small and large farmers respectively. One marginal and one large farmer had tractor/power tiller valued at Rs. 275000 and Rs. 370000, respectively. The value scarcely changed following development.

Considering the pooled farmers (Table 3.31), all farmers had land and dwelling house, while 74 per cent had livestock, 91 per cent farm implements, 24 per cent tube wells. Only a very small proportion had farm house, bullock carts and cattlesheds. There was hardly any increase in value of farm assets among all the three categories of the farmers.

Impact on calorie intake of farmers (Table 3.32). The food intake in terms of kcal per person per day was 2249.90, 2532.31 and 2602.72 among marginal, small and large farmers, respec-tively, before watershed development. These values increased to 2360.35, 2625.14 and 2727.57, respectively, after development. Hence, marginal farmers were consuming just the ICMR-recom-mended requirement (2250 kcal), before watershed development, whereas the average intake of small and large farmers was more than 2250 kcal even before development.

Expenditure on food per person per day worked out to Rs 5.55, Rs 6.98 and Rs 7.63 for marginal, small and large farmers, respectively, before development and increased to Rs 6.13, Rs 7.53 and Rs 8.79, respectively, after development.

Large farmers had the highest potential for increasing intake in terms of both calories and rupees per day per person.

Awareness of soil problems. The soil problems perceived by the Garakahalli farmers and their effect on productivity are presented in Table 3.33. Rank based quotient (RBQ) was calculated for different soil problems perceived by the farmer, higher RBQ reflects higher crop loss.

The RBQ for gravel/stoniness was 31.91, 30.88 and 31.58 among marginal, small and large farmers, respectively, with a perceived crop loss ranging from 11.5 to 17.3 per cent. As stoniness/gravelliness increases, the fertility and water-holding capacity of the soil decreases, resulting in low productivity. The RBQ for crusting (48.22), slope (30.03), perennial weeds (56.54), top-soil loss (33.43), loss of nutrients (33.19), loss of moisture (63.23), rill and gully formation (20.32) and uneven shape of land (17.61) were significant and perceived crop loss due to these soil problems was in the ranges 17.67–24.67, 13.00–17.67, 34.00–45.67, 14.00–22.00, 15.00–21.00, 21.67–24.00, 4.00–7.33 and 7.00–10.33, respectively.

Table 3.28 Change in value of farm assets of marginal farmers as a result of development in Garakahalli watershed

Asset	Before development		After development		Change	
	Num. of farmers	Av. value (Rs)	Num. of farmers	Av. value (Rs)	Num. of farmers	Av. value (Rs)
Land						
Rainfed	127	83400.00	127	84000.00	0	600.00
Irrigated	126	142700.00	126	142700.00	0	0.00
Livestock	120	3740.07	120	3796.21	0	56.14
Dwelling house	164	68990.00	164	68990.00	0	0.00
Cattleshed	0	0.00	2	10000.00	2	10000.00
Tubewell + pumpset	33	46497.00	33	48721.00	0	2224.00
Bullock cart	9	11333.00	9	11333.00	0	0.00
Tractor/power tiller	1	275000.00	1	275000.00	0	0.00
Farm implements	149	192.00	155	250.00	6	58.00
Farm house	3	4333.00	4	4580.00	1	247.00

Table 3.29 Change in value of farm assets of small farmers as a result of watershed development in Garakahalli watershed

Asset	Before development		After development		Change	
	Num. of farmers	Av. value (Rs)	Num. of farmers	Av. value (Rs)	Num. of farmers	Av. value (Rs)
Land						
Rainfed	49	85400.00	49	87707.50	0	2307.50
Irrigated	23	149100.00	23	151125.00	0	104.57
Livestock	50	3684.14	50	3788.71	0	104.57
Dwelling house	68	76620.00	68	76620.00	0	0.00
Cattleshed	1	5000.00	1	5000.00	0	167.00
Tubewell + pumpset	16	46500.00	17	46667.00	1	167.00
Bullock cart	4	8200.00	4	8700.00	0	500.00
Tractor/power tiller	0	0.00	0	0.00	0	00.00
Farm implements	63	169.00	65	280.00	2	111.00
Farm house	0	0.00	2	7500.00	2	7500.00

Table 3.30 Change in value of farm assets of large farmers as a result of development in Garakahalli watershed

Asset	Before development		After development		Change	
	Num. of farmers	Av. value (Rs)	Num. of farmers	Av. value (Rs)	Num. of farmers	Av. value (Rs)
Land						
Rainfed	12	84000.00	12	84000.00	0	0.00
Irrigated	11	149100.00	11	149100.00	0	0.00
Livestock	16	3749.57	16	3826.14	0	76.57
Dwelling house	19	120526.00	19	120526.00	0	0.00
Cattleshed	6	12000.00	8	13500.00	2	1500.00
Tubewell + pumpset	9	50417.00	10	50417.00	1	0.00
Bullock cart	1	12000.00	3	12000.00	2	0.00
Tractor/power tiller	1	370000.00	1	370000.00	0	0.00
Farm implements	17	181.00	19	350.00	2	169.00
Farm house	0	0.00	0	0.00	0	0.00

Table 3.31 Change in value of farm assets of pooled farmers as a result of development in Garakahalli watershed

Asset	Before development		After development		Change	
	Num. of farmers	Av. value (Rs)	Num. of farmers	Av. value (Rs)	Num. of farmers	Av. value (Rs)
Land						
Rainfed	188	84266.67	188	85235.83	0	969.16
Irrigated	160	146966.67	160	147641.67	0	675.00
Livestock	186	3724.59	186	3803.69	0	132.72
Dwelling house	251	88712.00	251	88712.00	0	0.00
Cattleshed	7	5666.67	11	9500.00	4	3833.33
Tubewell + pumpset	58	47804.67	60	48601.67	2	797.00
Bullock cart	14	10511.00	16	10677.67	2	166.67
Tractor/power tiller	2	322500.00	2	322500.00	0	0.00
Farm implements	229	180.67	239	293.33	10	112.67
Farm house	3	1444.33	6	4026.67	3	2582.33

Adoption of soil- and water-conservation practices. The data on adoption of conservation practices by farmers of the watershed (Table 3.34) show that summer ploughing was adopted by 156 marginal, 63 small and 18 large farmers, the expected crop loss if not adopted was 11.67–16.67 per cent. Opening of furrows was adopted by 72 marginal, 26 small and 6 large farmers to reduce runoff losses and conserve soil moisture. Sowing across the slope was adopted by 147 marginal, 60 small and 18 large farmers. The expected loss of crop if the practice were not adopted was 15.33–20.00 per cent. Scooping and mulching were followed by 21 and 6 farmers, respectively. Application of FYM was adopted by 163 marginal, 65 small and 18 large farmers and the crop loss expected from non-adoption was in the range 34.67–45 per cent. Silt addition was adopted by 79 marginal, 29 small and 11 large farmers and the expected crop loss consequent on non-adoption was in the range 7.67–12.00 per cent.

Reasons for non-adoption of soil and water conservation practices. At least one recom-mended soil- and water-conservation practice was not adopted by 76 marginal, 40 small and 19 large farmers (Table 3.35) for various reasons.

Marginal farmers quoted lack of funds (46%), uneconomical nature of the practice (29%) and small size of holding (24%) as reasons. Small farmers mentioned uneconomical nature (59%) and small size of holding (35%), whereas the 19 non-adopting large farmers mentioned just one reason, uneconomical nature.

3.4 Economic Evaluation of Investment in Garakahalli Watershed

The assumptions made in evaluating the worthiness of the investment of Rs 16,31,940.00 made in Garakahalli watershed were the same as for the other three watersheds. Data on the incremental net income flow over the economic life of the investment are given in Table 3.36. Results of the economic evaluation using four criteria, namely, pay-back period, net present worth and benefit:cost ratio are presented in Table 3.37.

Pay back period (PBP). The PBP criterion considers the undiscounted net incremental income to recover or pay back the initial amount of investment. The results showed that the pay back period was about 6.4 years, so that the aggregate net benefits realized from the watershed in this time would cover or pay back the entire macro-investment made. However, as this criterion does not recognize the time value of money, other criteria accounting for the time value of money were also employed in evaluating the worthiness of the project.

Net present worth (NPW). The net present worth (NPW) of the Garakahalli watershed project was Rs 1,95,379.20 at 12% discount rate. As the NPW is positive, investment in the watershed by the NWDPRA and farmers is economically feasible and financially sound.

Benefit:cost ratio (B:C Ratio). The discounted B:C ratio was used to estimate the return per rupee of investment made in the project. The B:C ratio was 1.146:1, which indicated that every one rupee of investment made in the watershed yielded an incremental net return of Rs 1.146.

Internal rate of return (IRR). The IRR was determined by the procedure given in Volume I, Chapter 3, § 3.4.4. The IRR was 13.39 per cent, indicating that a discount rate of 13.39 would make the net present value of the investments and costs in the watershed equal to the returns. Since the IRR is greater than the opportunity cost or the present lending rate, the investment in the Nalatwad watershed is economically feasible and viable as well as financially sound.

Table 3.36 Incremental net income flow over the years of the economic life of the investment in Garakahalli watershed

Year	Total investment Rs	Incremental net income Rs	Discount rate 12%		Discount rate 15%	
			Discount factor	Discounted net incremental income, Rs	Discount factor	Discounted net incremental income, Rs
Initial	1631940.00					
1		238974.59	0.893	213404.31	0.870	207907.89
2		238974.59	0.797	190462.75	0.756	180664.79
3		238974.59	0.712	170149.91	0.658	157245.28
4		238974.59	0.636	151987.84	0.572	136693.47
5		238974.59	0.567	135498.59	0.497	118770.37
6		262872.049	0.507	133276.13	0.432	113560.73
7		286769.508	0.452	129619.82	0.376	107825.34
8		310666.967	0.404	125509.45	0.327	101588.10
9		334564.426	0.361	120777.76	0.284	95016.30
10		358461.885	0.322	115424.73	0.247	88540.09
11		358461.885	0.287	102878.56	0.215	77069.31
12		215077.131	0.257	55274.82	0.187	40219.42
13		191179.672	0.229	43780.14	0.163	31162.29
14		167282.213	0.205	34292.85	0.141	23586.79
15		143384.754	0.183	26239.41	0.123	17636.32
16		119487.295	0.163	19476.43	0.107	12785.14
17		119487.295	0.146	17445.15	0.093	11112.32
18		119487.295	0.130	15533.35	0.081	9678.47
19		119487.295	0.116	13860.53	0.070	8364.11
20		119487.295	0.104	12426.68	0.061	7288.72
Total	**1631940.00**	**4421029.92**	**7.471**	**1827319.20**	**6.260**	**1546715.24**

Table 3.37 Pay-back period, net present worth, B:C ratio and IRR of the investment made in Garakahalli watershed

	Value
Pay Back Period, y	6.42
NPW @ 12%, Rs	195379.20
NPW @ 15%, Rs	–85224.76
B:C Ratio	1.146
IRR	13.39

3.5 Economic Analysis of Crop Enterprises in Garakahalli Watershed

3.5.1 Economics of groundnut

Costs and returns in groundnut cultivation. Data on cost of cultivation and returns per hectare of groundnut are presented in Table 3.38.

Groundnut-growing farmers (pooled) in the watershed on an average incurred per hectare Rs 1548.69 towards human labour, Rs 1243.56 towards bullock labour, Rs 1941.06 towards seed material, Rs 1607 towards manure and Rs 1141.62 towards fertilizers. Expenditure towards seed forms the major item at 23.32 per cent of the total cost. Next were expenditure towards manure and human labour, constituting 18.86 and 18.33 per cent, respectively.

The total operational cost of cultivation of groundnut per hectare was Rs 8721 for mar-ginal, Rs 9104 for small and Rs 7461 for large farmers.

On average the yield of groundnut was 7.43 qtl/ha of main product and 26.17 qtl/ha of by-product. The average gross returns were Rs 9637.92/ha with net return of Rs 1209.17/ha.

Yield gap analysis in groundnut. Data on levels of input use (FYM and NPK) and potential yield levels in Garakahalli watershed under recommended package and farmers' practices are presented in Table 3.39.

The recommended level of FYM for groundnut crop is 7.5 t/ha. Quantum of FYM use was low in marginal (3.74 t/ha), small (3.62 t/ha) and large (2.26 t/ha)

farmers. The average level of FYM use by pooled farmers as a whole was low (3.21 t/ha) with wide input gap of 4.29 t/ha (57.24 %). The recommended dose of NPK is 25–50–25 kg/ha along with 500 kg of gypsum. Marginal and large farmers were applying lower (18.78 to 22.58 kg/ha) amount of N and small farmers larger amount (28.84 kg/ha).

Use of phosphorus was high in small (72.87 kg/ha), moderate in marginal (56.12 kg/ha) and low in large (47.45 kg/ha) farmers as against the recommended dose (50 kg/ha). The pooled data indicates a high level of P application (58.81 kg/ha). Use of potash was abysmally low (99.2% gap in pooled farmers). The recommended NPK ratio is 1:2:1. In general, farmers were applying unbalanced fertilizers with the ratio 1:2.48:0.2 (marginal farmers) to 1:2.53:0 (small and large farmers). The ratio for pooled farmers was 1:2.51:0, with almost total non-application of K.

The recommended seed rate is 110 kg/ha. Marginal (77 kg/ha), small (72 kg/ha) and large (83 kg/ha) farmers were all using much lower seed rate. The rate for pooled farmers was 77.63 kg/ha with wide adoption gap of 32.37 kg/ha (29.43 per cent).

The potential yield under recommended practices is 9.0 qtl/ha. The yields recorded by marginal, small and large farmers were 7.61, 7.22 and 7.43 qtl/ha, respectively, with yield gap of 1.78 (small), 1.57 (large), and 1.39 qtl/ha (marginal farmers). The pooled yield was 7.43 qtl/ha with yield gap of was 1.57 qtl/ha (17.45%).

3.5.2 Economics of finger millet

Costs and returns in finger millet cultivation. Data on cost of cultivation per hectare of finger millet are given in Table 3.40. Farmers growing finger millet in the watershed on the whole spent Rs 1876.10/ha for human labour, Rs 1347.50/ha for bullock labour, Rs 157.63/ha for seed material, Rs 2229.41/ha for manure and Rs 1516.50/ha for fertilizers.

Human and bullock labour together formed the major cost component accounting for 40.26 per cent of the total. Thus cultivation of finger millet in this watershed is labour intensive rather than capital intensive. Seed cost formed a minute (just over 2%) portion of the total cost. This was in spite of the farmers using higher than the recommended seed rate (10–12 kg/ha). The reason for use of higher seed rate might be the risk of low germination.

The total operational cost of cultivation of finger millet including the interest on working capital was Rs 8014.30/ha. On average the yield from finger millet was 13.29 qtl/ha of main product and 21.15 qtl/ha of by-product. The average gross returns were Rs 9030.80/ha with net returns of Rs 1016.50/ha.

Yield gap analysis in finger millet. The data pertaining to yield gap in cultivation of finger millet are given in Table 3.41.

The recommended dose of FYM for finger millet crop is 7.5 t/ha, but marginal farmers (5.34 t/ha), small farmers (4.88 t/ha) and large farmers (3.06 t/ha) were applying considerably less, with input adoption gaps of 2.16, 2.62 and 4.44 t/ha respectively. The pooled data revealed that average FYM input gap was 3.07 t/ha (40.98%).

The recommended dose of N–P–K for finger millet crop is 50–40–25 kg/ha, while marginal (57.91–54.52–1.3 kg/ha), small (81.23–53.63–0.47 kg/ha) and large farmers (76.63–49.15–1.51 kg/ha) used more than the recommended doses of nitrogen and phosphorus but negligible amounts of potash with wide adoption gap.

Marginal (16.85 kg/ha), small (17.45 kg/ha) and large farmers (25.18 kg/ha) used more than the recommended seed rate (11 kg/ha). Among the different categories of farmers no single farmer was using plant protection chemicals to control pests and diseases in finger millet crop.

The yield of demonstration plot was 17.5 qtl/ha, while the average yield obtained by marginal farmers (actual farm yield) was 14.58 qtl/ha, resulting in average yield gap of 2.92 qtl/ha (16.69%). Among small and large farmers the average actual yield was 13.04 qtl/ha and 12.26 qtl/ha with yield gaps of 25.49 and 29.94

per cent. The average straw yield of demonstration plot was 3.5 t/ha, while the average yield in the marginal, small and large farmers' fields was 2.59, 2.23 and 1.51 t/ha.

Thus, in spite of using higher input of seed, N and P, the yields of finger millet recorded by farmers in the watershed were 17–30 per cent lower and yields of straw 26–57 per cent lower than the potential. This may partly be due to the very large adoption gap with regard to potash.

3.5.3 Economics of horsegram

Costs and returns in horsegram cultivation. Data on cost per hectare of cultivation of horse gram in Garakahalli watershed are given in Table 3.42.

The farmers growing horsegram spent for every hectare about Rs 517.84 for human labour, Rs 1028.20 towards bullock labour, Rs 238.23 for seed material, Rs 531.11 for manure and Rs 7.13 for fertilizers. Cost of bullock labour formed the major portion (38.77%) of the total cost of cultivation. The next largest component was expenditure on manure (20.02%).

No marginal or large farmer applied any fertilizer, while small farmers applied 2 kg/ha of nitrogen fertilizer. There was no input of phosphorus or potash fertilizer from any farmer.

The average cost of cultivation of horsegram including interest on working capital was Rs 2612.84/ha. Yield from horsegram per hectare was 4.37 qtl of main product and 6.68 qtl of by-product. The average gross returns were Rs 3125.32/ha with net returns of Rs 512.48/ha.

Yield gap analysis in horsegram. Results of yield gap analysis per hectare of horsegram are presented in Table 3.43. There is no recommendation on application of FYM for horsegram culti-vation, but the farmers applied whatever was available with them (marginal farmers 1.18 t/ha; small farmers 1.19 t/ha; large farmers 0.7 t/ha).

The recommendation for fertilizer N–P–K application is 25–38–25 kg/ha. Marginal and large farmers did not apply any fertilizer at all while small farmers

applied just 2.05 kg/ha of nitrogen fertilizer. The adoption gap of fertilizer input was very high among all the three groups of farmers.

The recommended seed rate for horsegram is 25 kg/ha; adoption gaps were 14.52 per cent for marginal farmers, 8.00 per cent for small farmers and (–)8.32 per cent for large farmers.

The average grain yield of demonstration plot was 9.0 qtl/ha, whereas the yield obtained by marginal (4.62 qtl/ha), small (4.43 qtl/ha) and large farmers (4.06 qtl/ha) were considerably lower, with yield gaps of 48.67, 50.78 and 54.89 per cent, respectively.

3.5.4 Economics of Banana

Costs and returns in banana cultivation. As seen from Table 3.44, banana-growing farmers in the watershed on average spent Rs 13,959.08/ha for human labour (24.49%), Rs 3434.21 for bullock labour (6.66%), Rs 7532.30 for planting material (14.41%), Rs 7343.48 for manure (13.53%) and Rs 11,551.63 for fertilizers (21.90%), Rs 1550.29 for plant protection chemicals (2.94%), Rs 1541.40 for irrigation (2.92%).

Expenditure for human labour formed the major component of cost (26.49 %) followed by fertilizers (21.91 %), planting material (14.45 %) and FYM (13.53 %).

On an average the yield of banana per hectare was 181.85 qtl of main product. The gross returns were Rs 1,27,294.20/ha with net returns of Rs 74,517.76/ha.

Yield gap analysis in banana. Results of yield gap analysis in banana in the watershed are presented in Table 3.45.

The recommended dose of FYM for banana is 60 t/ha, while marginal (8.91 t/ha), small (12.24 t/ha) and large farmers (22.89 t/ha) applied considerably less (51.09%, 47.76% and 37.11%) than the recommended dose.

Recommended dose of N–P–K fertilizer application is 400–240–500 kg/ha, but marginal (130.49–206.01–139.98 kg/ha), small (158.3–210.8–187.88 kg/ha) and large farmers (211.52–291.25–361.06 kg/ha) applied less than the

recommended level. Level of phosphorus application was closest to the recommended dose in marginal (14.16% map) and small farmers (gap of 12.17%); the adoption gap in large farmers was negative (–21.35%).

The recommended seed rate for banana is 2225 seedlings/ha, but marginal (1896/ha), small (2024/ha) and large farmers (1875/ha) were using fewer seedlings recommended.

The recommendation for the plant-protection chemical phorate is 22.25 kg/ha; the actual quantities used were 16.04 kg/ha (marginal), 16.19 kg/ha (small) and 16.35 kg/ha (large farmers). The yield of demonstration plots was 25 t/ha, but actual farm yields were 18.02 t/ha (marginal), 18.95 t/ha (small) and 17.57 t/ha (large farmers). The yield gaps were 28 per cent (marginal), 27 per cent (small) and 27 per cent (large farmers).

3.5.4 Economics of Rice

Costs and returns in rice cultivation. The data in Table 3.46 show that rice-growing farmers in the watershed annually spent about Rs 5395/ha for human labour, Rs 1406.32/ha for bullock labour, Rs 919.94/ha for seed material, Rs 4111.40/ha for manure and Rs 2705.14/ha for fertilizers, Rs 385.26/ha for plant-protection chemicals and Rs 300 for irrigation.

Human and bullock labour formed the major component, accounting for 38.28 per cent of the total cost, followed by cost of FYM and green manure, constituting 23.92 per cent. Fertilizer cost is 15.09 per cent of the total costs.

The cost of cultivation of rice including irrigation charges and interest on working capital was Rs 17,072.75/ha. On average the yield of grain 29.28 qtl/ha and of by-product 39.29 qtl/ha. The average gross returns were Rs 21,505.02/ha with net returns of Rs 4432.27/ha.

Yield gap analysis in rice. Results of yield gap analysis in rice in the watershed are presented in Table 3.47.

The recommendation for FYM for rice is 7.5 t/ha, while marginal, small and large far-mers applied respectively 6.06t/ha, 12.2 t/ha and 6.4 t/ha, that is, small

farmers applied more FYM than recommended and marginal and large farmers applied less, with input adoption gaps of 1.44 t/ha and 1.1 t/ha, respectively.

Marginal, small and large farmers applied 106.68–60.55–30.55, 91.1–32.82–12.25, 96.75–52.25–40.25 kg/ha, respectively, of N–P–K fertilizers against the recommended dose of 100–50–50 kg/ha. Thus marginal farmers applied more than the recommended dose, while small and large farmers applied less.

The recommended seed rate for rice is 62 kg/ha. Marginal (68.08 kg/ha), small (65.89 kg/ha) and large farmers (96 kg/ha) were using higher seed rate than recommended. The PPC used was Monocrotophos to an extent of 1.02, 0.81 and 1.07 L/ha among marginal, small and large farmers, respectively, against the recommended dose of 1.56 L/ha.

The yield from demonstration plots was 45 qtl/ha, while actual farm yields of marginal, small and large farmers were 25.19, 31.17 and 31.5 qtl/ha with 30–44 per cent yield gap.

3.5.5 Economics of mulberry

Cost of establishment of mulberry garden. Establishment costs are the costs incurred from the stage of planting of mulberry to the first harvest, but excluding the litter. Details of costs of establishment of one hectare of mulberry garden in the watershed are given in Table 3.48.

The total cost of establishment was Rs 9870.28/ha of which the costs of land preparation, planting and maintenance, and inputs were Rs 1692.96/ha, Rs 3529.69/ha and 3912.24/ha, respectively. In the total cost of establishment, the share of land preparation was 24.60 per cent, composed of 7.45 per cent for human labour and 17.15 per cent for bullock labour. Planting of cuttings and maintenance consumed a major proportion of human labour (35.75%). The cost of inputs constituted 39.61 per cent of the establishment cost. Of the various inputs used, the share of irrigation charges was the highest (Rs 1541.40) followed by cost of manure (Rs 1511.73), cost of cuttings (Rs 392.08) and cost of fertilizers (Rs 293.63).

Physical input-output relations in mulberry cultivation. The annual inputs per hectare com-puted for mulberry are given in Table 3.49.

The inputs were composed of 198.05 man-days of human labour and 17.75 pair-days of bullock labour, 17.75 quintals of FYM, 252.34 kg of nitrogen fertilizer, 111.23 kg of P fertilizer and 103.15 kg potash fertilizer.

The output of mulberry leaves was 29056.34 kg/ha.

Table 3.49 Annual physical input–output relations per ha of mulberry crop in Garakahalli watershed

Particulars	Unit	Quantity
Input		
Human labour	man-days	198.05
Bullock labour	pair-days	17.75
Farmyard manure	qtl	60.04
Nitrogen	kg	252.34
Phosphorus	kg	111.23
Potash	kg	103.15
Output		
Mulberry leaves	kg	29056.34

Labour requirement in mulberry cultivation. Sericulture is a labour-intensive activity consu-ming labour for production of mulberry leaves and of silk cocoons. In the production of mulberry leaves, labour is employed for weeding and intercultivation, application of manure and fertilizers, irrigation and pruning. Data on the annual labour requirement per hectare of mulberry garden are presented in Table 3.50.

The total labour required per hectare is 198.05 man-days of human labour and 17.75 pair-days of bullock labour. Out of these, 80.04 man-days (40.41 %) and 17.75 pair-days (100 %) are used for weeding and intercultivation, while

remaining human labour of 118.01 man-days (59.59 %) is used for irrigation, application of plant nutrients and pruning. In Garakahalli watershed, about half (50.85%) of human labour was contributed by the family and the rest hired.

Cost of cultivation of mulberry crop. The costs incurred in mulberry cultivation per hectare are presented in Table 3.51. The total cost included the cost of human labour, bullock labour, FYM, fertilizers, irrigation and interest on working capital, and amounted to Rs 20425.82. Of the operational costs, the highest expenditure was incurred on human labour (Rs 7922) followed by cost of FYM (Rs 3000).

Table 3.50 Annual labour requirement per ha in mulberry cultivation in Garakahalli watershed

Operation	Human labour (man-days)				Bullock labour (pair-days)			
	Family	Hired	Total	% of total labour/ha	Family	Hired	Total	% of total labour/ha
Land preparation, intercultivation	31.52	48.52	80.04	40.41	12.50	5.25	17.75	100.00
Irrigation	42.35	0	42.35	21.38	0	0	0	0
Application of fertilizers, manures	12.60	14.56	48.50	24.48	0	0	0	0
Pruning	14.25	34.25	48.50	24.48	0	0	0	0
Total	100.72	97.33	198.05	100.00	12.50	5.25	17.75	100.00

Table 3.51 Annual cost of cultivation per ha of mulberry crop in Garakahalli watershed

Item	Cost, Rs
Human labour	7922.00
Bullock labour	2662.50
Farmyard manure	3000.00
Fertilizers	2514.06
Interest on working capital	2204.99
Irrigation	1541.40
Establishment (apportioned)	580.87
Total	**20425.82**

3.5.6 Economics of silk cocoon production

Physical input-output relations for silk cocoon production. The physical input-output rela-tions for silk cocoon production from one hectare of mulberry garden in Garakahalli watershed are presented in Table 3.52. Silk cocoon

production consumed 486.72 man-days/ha of human labour excluding the labour spent on producing the mulberry leaf consumed. The farmers produced 1555 kg/ha of cocoon from an average of 5 rearings.

Cost of silk cocoon production. The costs pertaining of silk cocoon production are presented in Table 3.53. The total cost of silk production was Rs 63,903.67/ha. In the total cost the expen-diture on mulberry leaves was greatest (Rs 26,711.75) followed by human labour costs (Rs 19,468.80), interest on working capital (Rs 7314.55), cost of the layings (Rs 6250), hire charges of bamboo baskets and mountings (Rs 2576.45), cost of disinfectants (Rs1124.12) and miscellaneous costs (Rs 112).

Returns from silk cocoon production. Data on the returns obtained from silk cocoon production per hectare mulberry garden are presented in Table 3.54.

Sale of the 1555 kg of cocoons, the main product, fetched Rs 1,24,400.00. The by-products of the enterprise were 32.25 qtl of litter and 44.87 qtl of fodder. The net returns per hectare were Rs 60,496.33.

Table 3.52 Annual physical input–output relations in silk cocoon production per ha of mulberry crop in Garakahalli watershed

Particulars	Unit	Quantity
Input		
Layings	number	2550
Mulberry leaves	kg	29056.34
Human labour	man-days	486.72
Output		
Cocoons	kg	1555
By-product		
Litter	qtl	32.25
Leftover fodder	qtl	44.87

Table 3.53 Annual cost of silk cocoon production per ha of mulberry crop in Garakahalli watershed

Item	Cost, Rs
Layings	6250.00
Human labour	19468.80
Disinfectants	1125.12
Hire charges for baskets and mountages	2576.45
Mulberry leaves	26711.75
Marketing costs	525.00

Interest on working capital	7134.55
Miscellaneous costs	112.00
Total	**63903.67**

Table 3.54 Returns from silk cocoon production per ha of mulberry crop in Garakahalli watershed

Item	Quantity	Value, Rs
Silk cocoons	1555 kg	124400.00
Gross returns		124400.00
Total cost		63903.67
Net returns		60496.33

3.5.7 Economics of coconut cultivation

Investment in coconut gardens was categorized into establishment and maintenance costs. Expenses on inputs and labour and imported costs on home produced inputs in the watershed were considered in estimation of costs.

Establishment cost. Establishment cost included the labour and material cost for operations such as land preparation, peg marking and digging of pits, planting of seedlings, manuring and fertilizer application, fencing the land, after-care operations during the first year and all the costs incurred (material and labour) in maintaining the garden till it comes to bearing in the fifth year.

Cost of establishment per hectare for the first five years are given in Table 3.55.

Table 3.55 Cost (Rs/ha) of establishment of coconut garden in Garakahalli watershed

Particulars	Year					Total
	I	II	III	IV	V	
Labour costs						
Land preparation	338.56	293.85	309.98	242.21	234.60	1419.72
Peg marking, digging pits	285.35	0	0	0	0	285.35
Fencing	275.58	0	0	37.73	30.06	343.37
Planting	367.65	6.5	0	0	0	374.15
Fertilizer application	462.61	287.74	310.13	360.86	305.60	1726.94
Cleaning, widening basins	0	158.55	258.36	250.48	270.85	938.25
Irrigation	235.27	141.89	0	0	0	377.16
Watch and ward, weeding	0	0	0	0	0	0
Bunding	377.74	217.81	266.70	236.05	303.45	1401.75
Subtotal	2342.78	1106.35	1145.19	1127.84	1144.56	6866.72
Material costs						
Fencing material	1148.77	0	0	0	0	1148.77
Seedling/seed material	3844.20	124.99	0	0	0	3969.19
Manures, FYM	1686.84	591.59	668.21	628.91	879.38	4454.93

Fertilizers	190.42	218.81	202.01	276.78	269.63	1157.67
Others (oilcakes)	604.15	0	0	0	0	604.15
Subtotal	7474.39	935.40	870.22	905.69	1149.01	11334.72
Total	**9817.17**	**2041.75**	**2015.41**	**2033.54**	**2293.57**	**18201.45**

The total labour and material cost (inputs) was Rs 18201.45/ha, of which labour cost accounted for Rs 6866.72 (37.22 %), while material cost worked out to Rs 11,334.72 (62.27 %) for the first five years of establishment. The first year represents the actual establishment and the following four years the maintenance expenditure. However, since no bearing is seen during these five years it is considered as establishment period. The cost incurred during first year of establishment accounted for 53.93 per cent (Rs 9817.17) of the total establishment cost.

Maintenance cost. Maintenance costs considered for a bearing coconut garden (Table 3.56) are various cultivation costs such as labour costs for cultural operations, cost of inputs and other charges incurred each year after the garden comes to maturity or regular bearing.

The expenditure on labour was Rs 3968.98/ha. The labour cost for harvesting, collecting and transporting nuts to the storehouse formed the largest component of Rs 1045.80 followed by manuring and fertilizer application (Rs 933.44), dehusking, bagging and transportation to market (Rs 583.37), land preparation (Rs 356.79), cleaning and widening of basins (Rs 346.07) and watch and ward (Rs 303.72). Cost of materials for fencing, FYM, red earth, oilcakes, fertilizers, replacement seedlings were Rs 577.22, 6571.91, Rs 1315.23, Rs 1200.71, Rs 1506.07 and Rs 883.34, respectively. Cost of FYM took the largest share of material cost followed by fertilizers, red earth, seedlings, fencing material. The total annual maintenance cost for bearing coconut gardens was Rs 17,395.01/ha.

Yields and returns from coconut gardens. Annual yield and returns from ripened coconuts per hectare are presented in Table 3.57. Farmers harvested 9092 nuts ha^{-1} y^{-1}. The price realized was Rs 2491 per 1000 nuts. The number of dry fronds obtained was 1483 and price realized Rs 500 per 1000 fronds. Thus gross returns were Rs 23,388.50/ha and net returns Rs 8415.49/ha.

Table 3.4 Farm household occupational pattern in Garakahalli watershed

Occupation		Marginal farm households		Small farm households		Large farm households		Pooled households	
Main	Subsidiary	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Crop production	Agric. labour	28	17.07	7	10.29	0	0.00	35	13.94
Crop production	Sericulture	61	37.20	42	61.76	10	52.63	113	45.02
Agric. labour	Crop production	32	19.51	0	0.00	0	0.00	32	12.75
Crop production	Sheep, goat rearing	7	4.27	5	7.35	2	10.53	14	5.58
Crop production	Dairy enterprise	29	17.68	12	17.65	5	26.32	46	18.33
Rural artisanship	Crop production	1	0.61	0	0.00	0	0.00	1	0.40
Crop production	Business	3	1.83	2	2.94	1	5.26	6	2.39
Govt service	Crop production	3	1.83	0	0.00	1	5.26	4	1.59
Total		164	100.00	68	100.00	19	100.00	251	100.00

Table 3.6 Average annual income of farm households in Garakahalli watershed

Source	Marginal farm households		Small farm households		Large farm households		Pooled farm households	
	Rs	Per cent	Rs	Per cent	Rs	Per cent	Rs	Per cent
Crop production	10159.48	31.52	18299.83	36.94	23253.98	44.38	17237.76	38.68
Agric. labour	1350.65	4.19	0.00	0.00	0.00	0.00	450.22	1.01
Sheep, goat rearing	1575.45	4.89	1350.42	2.73	1425.50	2.72	1450.46	3.25
Dairy enterprise	3425.63	10.63	2980.56	6.02	2550.65	4.87	2985.61	6.70
Sericulture	13165.86	40.85	22930.82	46.29	20104.35	38.37	18733.68	42.03
Business	1250.00	3.88	3975.50	8.03	4585.70	8.75	3270.40	7.34
Govt service	850.00	2.64	0.00	0.00	475.60	0.91	441.87	0.99
Rural artisanship	455.85	1.41	0.00	0.00	0.00	0.00	151.95	0.34
Total	**32232.92**	**100.00**	**49537.13**	**100.00**	**52395.78**	**100.00**	**44569.99**	**100.00**

Table 3.7 Distribution of land holdings in Garakahalli watershed

Particulars	Marginal farmers		Small farmers		Large farmers		Pooled farmers	
	ha	Per cent	ha	Per cent	ha	Per cent	ha	Per cent
Owned cultivable land								
Rainfed	78.536	73.88	95.44	74.98	46.944	64.25	220.92	72.04
Irrigated	27.16	25.55	29.76	23.38	26.12	35.75	83.04	27.08
Leased-in land								
Rainfed	0.20	0.19	1.84	1.45	0.00	0.00	2.04	0.67
Irrigated	0.40	0.38	0.25	0.20	0.00	0.00	0.65	0.21
Total operational area	106.30	100.00	127.29	100.00	73.064	100.00	306.65	100.00

Table 3.8 Livestock population among farm households in Garakahalli watershed

Livestock	Marginal farmers		Small farmers		Large farmers		Pooled farmers	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Bullocks	18	3.15	20	7.07	8	10.96	46	4.96
Dual-purpose cows	140	24.52	60	21.20	12	16.44	212	22.87
Crossbred cows	35	6.13	25	8.83	9	12.33	69	7.44
Buffaloes	64	11.21	33	11.66	13	17.81	110	11.87
Poultry	10	1.75	16	5.65	0	0.00	26	2.80
Sheep	200	35.03	65	22.97	17	23.29	282	30.42
Goats	104	18.21	64	22.61	14	19.18	182	19.63
TOTAL	**571**	**100.00**	**283**	**100.00**	**73**	**100.00**	**927**	**100.00**

Table 3.10 Tenurial status of farmers in Garakahalli watershed

Particulars	Marginal farmers		Small farmers		Large farmers		Pooled farmers	
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
Farmers having land records and rights in own name	129	78.66	58	85.29	15	78.95	202	80.48
Farmers not having land records in own name	35	21.34	10	14.71	4	21.05	49	19.52
Reasons for possessing land records								
Security	113	68.90	46	67.65	7	36.84	166	66.14
Prestige	11	6.71	4	5.88	8	42.11	23	9.16
Self satisfaction	44	26.83	24	35.29	4	21.05	72	28.69
For taking bank loan	11	6.71	11	16.18	3	15.79	25	9.96
Reasons for not having land records								
Family disputes	28	17.07	8	11.76	4	21.05	40	15.94
Litigation	3	1.83	1	1.47	2	10.53	6	2.39
High cost of registration	4	2.44	–	–	–	–	4	1.59

Table 3.15 Change in cropping pattern as a result of watershed development among marginal farmers of Garakahalli watershed

Crop	Before development				After development				Change			
	Kharif		*Rabi*/summer		*Kharif*		*Rabi*/summer		*Kharif*		*Rabi*/summer	
	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %
Rainfed crops												
Coconut	2.27	2.89	2.27	2.88	2.67	3.39	2.67	3.39	0.40	0.51	0.40	0.51
Groundnut	7.18	9.12	0.00	0.00	7.18	9.12	0.00	0.00	0.00	0.00	0.00	0.00
Finger millet	58.44	74.23	0.00	0.00	61.44	78.04	0.00	0.00	3.00	3.81	0.00	0.00
Horsegram	7.29	9.26	0.00	0.00	6.09	7.74	0.00	0.00	–1.20	–1.52	0.00	0.00
Fallow	3.55	4.51	76.47	97.12	1.35	1.71	76.07	96.61	–2.20	–2.79	–0.40	–0.51
Total	78.74	100.00	78.74	100.00	78.74	100.00	78.74	100.00	0.00	0.00	0.00	0.00
Irrigated crops												
Banana	2.20	9.48	2.20	8.07	2.74	9.94	2.74	9.94	0.54	0.46	0.54	1.87
Coconut	7.03	30.29	7.03	25.79	7.03	25.51	7.03	25.50	0.00	–4.78	0.00	–0.28
Mulberry	8.94	38.52	8.94	32.80	9.56	34.70	9.56	34.70	0.62	–3.81	0.62	1.90
Rice	1.40	6.03	0.60	2.20	1.96	7.11	1.10	3.99	0.56	1.08	0.50	1.79
Finger millet	3.34	14.39	2.25	8.25	4.35	15.79	3.25	11.79	1.01	1.40	1.00	3.54
Fallow	0.30	1.29	6.24	22.89	1.91	6.94	3.88	14.08	1.61	5.65	–2.36	–8.81
Total	23.21	100.00	27.26	100.00	27.56	100.00	27.56	100.00	4.35	0.00	0.30	0.00
GRAND TOTAL	106.30		106.30		106.30		106.30		0.00	0.00	0.00	0.00
Cropping intensity, % (excluding fallow)	123.03				125.58				2.60			

Table 3.16 Change in cropping pattern as a result of watershed development among small farmers of Garakahalli watershed

Crop	Before development				After development				Change			
	Kharif		*Rabi*/summer		*Kharif*		*Rabi*/summer		*Kharif*		*Rabi*/summer	
	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %
Rainfed crops												
Coconut	4.56	4.69	4.56	4.69	4.56	4.68	4.56	4.68	0.00	0.00	0.00	0.00
Groundnut	14.20	14.60	0.00	0.00	16.90	17.38	0.00	0.00	2.70	2.78	0.00	0.00
Finger millet	55.40	56.95	0.00	0.00	59.68	61.35	0.00	0.00	4.28	4.40	0.00	0.00
Horsegram	14.36	14.76	0.00	0.00	12.19	12.53	0.00	0.00	–2.17	–2.23	0.00	0.00
Fallow	8.76	9.00	92.72	95.31	3.95	4.06	92.72	95.32	–4.81	–4.95	0.00	0.00
Total	97.28	100.00	97.28	100.00	97.28	100.00	97.28	100.00	0.00	0.00	0.00	0.00
Irrigated crops												
Banana	5.45	18.16	5.45	18.16	6.00	19.99	6.00	19.99	0.55	1.83	0.55	1.83
Coconut	5.82	19.39	5.82	19.39	6.03	20.09	6.03	20.09	0.21	0.70	0.21	0.70
Mulberry	8.89	29.62	8.89	29.62	9.22	30.72	9.22	30.72	0.33	1.10	0.33	1.10
Rice	2.64	8.80	1.00	3.33	3.10	10.33	1.50	5.00	0.46	1.53	0.50	1.67
Finger millet	3.12	10.40	2.54	8.46	3.58	11.93	2.85	9.50	0.46	1.53	0.31	1.03
Sugarcane	0.00	0.00	0.00	0.00	0.40	1.33	0.40	1.33	0.40	1.33	0.40	1.33
Groundnut	0.00	0.00	0.00	0.00	0.40	1.33	0.40	1.33	0.40	1.33	0.00	0.00
Fallow	4.09	13.63	2.31	7.70	1.28	4.27	4.01	13.36	–2.81	–9.36	1.70	5.66
Total	30.01	100.00	30.01	100.00	30.01	100.00	30.01	100.00	0.00	0.00	0.00	0.00
GRAND TOTAL	127.29		127.29		127.29		127.29		0.00	0.00	0.00	0.00
Cropping intensity, % (excluding fallow)	128.19				125.03				–3.16			

Table 3.17 Change in cropping pattern as a result of watershed development among large farmers of Garakahalli watershed

Crop	Before development				After development				Change			
	Kharif		*Rabi*/summer		*Kharif*		*Rabi*/summer		*Kharif*		*Rabi*/summer	
	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %
Rainfed crops												
Coconut	2.2	4.69	2.2	4.69	2.50	5.33	2.50	5.33	0.30	0.64	0.30	0.64
Groundnut	9.45	20.14	0.00	0.00	12.92	27.54	0.00	0.00	3.47	7.40	0.00	0.00
Finger millet	21.16	45.10	0.00	0.00	24.10	51.36	0.00	0.00	2.94	6.27	0.00	0.00
Horsegram	8.2	17.48	0.00	0.00	4.35	9.27	0.00	0.00	–3.85	–8.21	0.00	0.00
Fallow	5.91	12.60	44.72	95.31	3.05	6.50	44.42	94.67	–2.86	–6.09	–0.30	–0.64
Total	46.92	100.00	46.92	100.00	46.92	100.00	46.92	100.00	0	0.00	0.00	0.00
Irrigated crops												
Banana	7.80	29.86	7.8	29.86	8.80	33.69	8.80	33.69	1.00	3.83	1.00	3.83
Coconut	5.85	22.40	5.85	22.40	6.05	23.17	6.05	23.17	0.20	0.77	0.20	0.77
Mulberry	2.75	10.53	2.75	10.53	3.34	12.79	3.34	12.79	0.59	2.26	0.59	2.26
Rice	2.25	8.61	1.00	3.83	2.39	9.15	1.00	3.83	0.14	0.54	0.00	0.00
Finger millet	2.18	8.35	1.50	5.74	2.41	9.23	1.50	5.74	0.23	0.88	0.00	0.00
Mango	1.4	5.36	1.40	5.36	1.40	5.36	1.40	5.36	0.00	0.00	0.00	0.00
Fallow	3.89	14.89	5.82	22.28	1.73	6.62	4.03	15.43	–2.16	–8.28	–1.79	–6.85
Total	26.12	100.00	26.12	100.00	26.12	100.00	26.12	100.00	0.00	0.00	0.00	0.00
GRAND TOTAL	73.04		73.04		73.04		73.04		0.00	0.00	0.00	0.00
Cropping intensity, % (excluding fallow)	135.58				136.03				0.45			

Table 3.18 Change in cropping pattern as a result of watershed development among pooled farmers of Garakahalli watershed

Crop	Before development				After development				Change			
	Kharif		*Rabi*/summer		*Kharif*		*Rabi*/summer		*Kharif*		*Rabi*/summer	
	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %	Area, ha	Area, %
Rainfed crops												
Coconut	9.03	4.07	9.03	4.07	9.73	4.36	9.73	4.36	0.69	0.29	0.70	0.29
Groundnut	30.83	13.90	0.00	0.00	37.00	16.60	0.00	0.00	6.17	2.69	0.00	0.00
Finger millet	135.00	60.88	0.00	0.00	145.22	65.14	0.00	0.00	10.22	4.25	0.00	0.00
Horsegram	29.85	13.46	0.00	0.00	22.63	10.15	0.00	0.00	–7.22	–3.31	0.00	0.00
Fallow	17.02	7.68	212.71	95.93	8.36	3.75	213.21	95.64	–8.66	–3.93	0.50	–0.29
Total	221.74	100.00	221.74	100.00	222.94	100.00	222.94	100.00	1.21	0.00	1.20	0.00
Irrigated crops												
Banana	15.45	19.47	15.45	19.46	17.54	20.96	17.54	20.96	2.09	2.40	2.09	2.40
Coconut	18.70	23.57	18.70	23.55	19.11	22.84	19.11	22.84	0.41	0.37	0.41	0.37
Mulberry	20.58	25.94	20.58	25.92	22.12	26.44	22.12	26.43	1.54	1.71	1.54	1.71
Rice	6.29	7.93	2.60	3.27	7.45	8.90	3.60	4.30	1.16	1.35	1.00	1.18
Finger millet	8.64	10.89	6.29	7.92	10.34	12.36	7.60	9.08	1.70	1.98	1.31	1.52
Mango	1.40	1.76	1.40	1.76	1.4	1.67	1.4	1.67	0.00	–0.01	0.00	0.00
Sugarcane	0.00	0.00	0.00	0.00	0.40	0.48	0.40	0.48	0.40	0.48	0.40	0.48
Groundnut	0.00	0.00	0.00	0.00	0.40	0.48	0.00	0.00	0.40	0.48	0.00	0.00
Fallow	8.28	10.44	14.37	18.10	4.92	5.88	11.92	14.24	–3.36	–8.75	–6.30	–7.65
Total	79.34	100.00	79.39	100.00	83.69	100.00	83.70	100.00	4.35	0.00	0.46	0.00
GRAND TOTAL	306.63		306.63		306.63		306.63		0	0.00	0.00	0.00
Cropping intensity, % (excluding fallow)	127.97				127.78				–0.19			

Table 3.19 Change in livestock population as a result of watershed development among marginal farmers of Garakahalli watershed

Livestock	Before development			After development			Change		
	Households	Animals	Av. value per animal (Rs)	Households	Animals	Av. value per animal (Rs)	Households	Animals	Av. value per animal (Rs)
Bullocks	9	18	5235.00	9	18	5422.00	0	0	187.00
Dual-purpose cows	70	140	4977.00	72	144	5125.00	2	4	148.00
Crossbred cows	22	35	10000.00	25	42	10000.00	3	7	0.00
Buffaloes	49	64	3926.00	57	77	3975.00	8	13	49.00
Poultry birds	3	10	42.50	4	33	51.50	1	23	9.00
Sheep	29	200	1000.00	30	320	1000.00	1	120	0.00
Goats	22	104	1000.00	22	189	1000.00	0	85	0.00
Total	–	571	26180.50	–	823	26573.50	–	253	393.00
Average	–	81.57	3740.07	–	117.57	3796.21	–	36.14	56.14
Households having no livestock	44	–	–	44	–	–	0	–	–
Households having no bullocks/dual-purpose cows	85	–	–	83	–	–	–2	–	–

Table 3.20 Change in livestock population as a result of watershed development among small farmers of Garakahalli watershed

Livestock	Before development			After development			Change		
	Households	Animals	Av. value per animal (Rs)	Households	Animals	Av. value per animal (Rs)	Households	Animals	Av. value per animal (Rs)
Bullocks	10	20	4300.00	10	20	4300.00	0	0	0.00
Dual-purpose cows	30	60	4452.00	34	68	4572.00	4	8	120.00
Crossbred cows	14	25	10500.00	16	30	11000.00	2	5	500.00
Buffaloes	26	33	4424.00	33	49	4490.00	7	16	66.00
Poultry birds	2	16	113.00	2	18	159.00	0	2	46.00
Sheep	11	65	1000.00	12	105	1000.00	1	40	0.00
Goats	12	64	1000.00	12	108	1000.00	0	44	0.00
Total	–	283	25789.00	–	398	26521.00	–	115	732.00
Average	–	40.43	3684.14	–	56.86	3788.71	–	16.43	104.57
Households having no livestock	10	–	–	9	–	–	–1	–	–
Households having no bullocks/dual-purpose cows	28	–	–	24	–	–	–4	–	–

Table 3.21 Change in livestock population as a result of watershed development among large farmers of Garakahalli watershed

Livestock	Before development			After development			Change		
	Households	Animals	Av. value per animal (Rs)	Households	Animals	Av. value per animal (Rs)	Households	Animals	Av. value per animal (Rs)
Bullocks	4	8	4500.00	4	8	4500.00	0	0	0.00
Dual-purpose cows	6	12	5132.00	8	16	5188.00	2	4	56.00
Crossbred cows	4	9	11000.00	5	12	11000.00	1	3	0.00
Buffaloes	9	13	3615.00	11	21	4095.00	2	8	480.00
Poultry birds	0	0	0.00	0	0	0.00	0	0	0.00
Sheep	2	17	1000.00	2	30	1000.00	0	13	0.00
Goats	2	14	1000.00	2	24	1000.00	0	10	0.00
Total	–	73	26247.00	–	111	26783.00	–	38	536.00
Average	–	10.43	3749.57	–	15.86	3826.14	–	5.43	76.57
Households having no livestock	3	–	–	3	–	–	0	–	–
Households having no bullocks/dual-purpose cows	9	–	–	7	–	–	–2	–	–

Table 3.22 Change in livestock population as a result of watershed development among pooled farmers of Garakahalli watershed

Livestock	Before development			After development			Change		
	Households	Animals	Av. value per animal (Rs)	Households	Animals	Av. value per animal (Rs)	Households	Animals	Av. value per animal (Rs)
Bullocks	23	46	4678.33	23	46	4740.67	0	0	62.33
Dual-purpose cows	106	212	4853.67	114	228	4961.67	8	16	108.00
Crossbred cows	40	69	10500.00	46	84	10666.67	6	15	166.67
Buffaloes	84	110	3988.33	101	147	4186.67	17	37	198.33
Poultry birds	5	26	51.83	6	51	70.17	1	25	18.33
Sheep	42	282	1000.00	44	455	1000.00	2	173	0.00
Goats	36	182	1000.00	36	321	1000.00	0	139	0.00
Total	–	927	26072.17	–	1332	26625.83	–	406	553.67
Average	–	264.86	3724.60	–	190.29	3803.69	–	58	79.10
Households having no livestock	57	–	–	56	–	–	–1	–	–
Households having no bullocks/dual-purpose cows	122	–	–	114	–	–	–8	–	–

Table 3.23 Change in agro-biodiversity in Garakahalli watershed due to watershed development

Type of tree	Number of trees											
	Before watershed project implementation				After watershed project implementation				Change due to water project implementation			
	Marginal farmers	Small farmers	Large farmers	Pooled	Marginal farmers	Small farmers	Large farmers	Pooled	Marginal farmers	Small farmers	Large farmers	Pooled
Acacia	5	0	0	5	10	0	0	10	5	0	0	5
Ankole	28	0	0	28	35	0	2	37	7	0	2	9
Baghe	2	0	0	2	7	0	0	7	5	0	0	5
Bersy	0	0	0	0	9	0	0	9	9	0	0	9
Coconut	15	11	2	28	454	75	38	567	439	64	36	539
Eucalyptus	7	0	0	7	16	0	0	16	9	0	0	9
Jack	1	0	3	4	1	0	9	10	0	0	6	6
Mango	106	10	0	116	1024	162	41	1227	918	152	41	1111
Neem	111	36	21	168	131	94	45	270	20	58	24	102
Pomegranate	0	0	0	0	4	0	0	4	4	0	0	4
Pongamia	20	12	0	32	36	32	3	71	16	20	3	39
Sapota	0	0	0	0	8	0	0	8	8	0	0	8
Silver oak	0	0	0	0	77	0	0	77	77	0	0	77
Tamarind	0	0	0	0	3	3	0	6	3	3	0	6
Teak	0	3	30	33	365	41	59	465	365	38	29	432

Table 3.32 Change in daily calorie intake *per capita* among the farmers following watershed development in Garakahalli watershed

Item	Before development				After development				Change			
	Marginal	Small	Large	Pooled	Marginal	Small	Large	Pooled	Marginal	Small	Large	Pooled
	Kilocalories per day *per capita*											
Cereals	1941.60	2092.27	2096.07	2043.31	1987.87	2092.27	2142.33	2074.16	46.27	0.00	46.27	30.84
Pulses	101.03	145.90	146.23	131.06	112.90	169.57	158.27	146.91	11.87	23.67	12.03	15.86
Veg., fruits	50.02	112.42	134.08	98.84	51.58	113.18	141.55	102.11	1.57	0.77	7.47	3.27
Meat, eggs	20.00	31.67	43.3333	31.67	25.00	43.33	56.67	41.67	5.00	10.00	13.33	10.00
Veg. oil	137.25	150.06	183.00	156.77	183.00	206.79	228.75	206.18	45.75	56.73	45.75	49.41
Total	**2249.90**	**2532.31**	**2602.72**	**2461.64**	**2360.35**	**2625.14**	**2727.57**	**2571.02**	**110.45**	**91.16**	**124.85**	**109.37**
	Rs per day *per capita*											
Cereals	3.47	4.17	4.57	4.07	4.10	4.17	4.90	4.39	0.63	0.00	0.80	0.32
Pulses	0.90	1.30	1.40	1.20	1.20	1.50	1.60	1.43	0.30	0.20	0.40	0.23
Veg., fruits	0.45	0.52	0.53	0.50	0.46	0.53	0.57	0.52	0.01	0.01	0.11	0.02
Meat, eggs	0.43	0.59	0.74	0.59	0.50	0.89	1.12	0.84	0.07	0.30	0.62	0.25
Veg. oil	0.30	0.40	0.40	0.37	0.40	0.83	0.60	0.61	0.10	0.43	0.20	0.24
Total	**5.55**	**6.98**	**7.63**	**6.72**	**6.13**	**7.53**	**8.79**	**7.48**	**0.59**	**0.55**	**1.15**	**0.76**

Table 3.33 Awareness of soil problems among the farmers of Garakahalli watershed

Soil problem	Marginal farmers			Small farmers			Large farmers			Pooled		
	RBQ	Crop loss (%)		RBQ	Crop loss (%)		RBQ	Crop loss (%)		RBQ	Crop loss (%)	
		Min	Max		Min	Max		Min	Max		Min	Max
Gravelliness/stones	31.91	11.00	17.00	30.88	11.00	17.00	31.58	12.00	18.00	31.46	11.33	17.33
Crusting	45.73	17.00	23.00	48.04	16.00	23.00	50.88	20.00	28.00	48.22	17.67	24.67
Sandy soil	7.11	3.00	5.00	6.37	3.00	4.00	7.02	3.00	6.00	6.83	3.00	5.00
Clayey soil	0.81	0.20	0.40	0.98	0.50	1.00	0.00	0.00	0.00	0.60	0.23	0.47
Sloping land	30.08	13.00	18.00	28.43	13.00	17.00	31.58	13.00	18.00	30.03	13.00	17.67
Shallow soil	5.69	1.30	2.00	1.47	0.20	0.50	3.51	1.00	2.00	3.56	0.83	1.50
Perennial weeds	58.30	34.00	44.00	53.43	32.00	42.00	57.89	36.00	51.00	56.54	34.00	45.67
Uneven land shape	16.67	6.00	9.00	18.63	7.00	11.00	17.54	8.00	11.00	17.61	7.00	10.33
Poor infiltration	1.22	0.10	0.30	0.49	0.07	0.10	0.00	0.00	0.00	0.57	0.06	0.13
Loss of topsoil	33.13	13.00	21.00	33.82	14.00	23.00	33.33	15.00	22.00	33.43	14.00	22.00
Loss of nutrients	32.93	13.00	20.00	33.30	14.00	19.00	33.33	18.00	24.00	33.19	15.00	21.00
Rooting depth loss	7.52	2.00	3.00	6.86	1.00	8.00	14.04	2.00	4.00	9.47	1.67	5.00
Loss of moisture	60.77	21.00	26.00	62.25	22.00	19.00	66.67	22.00	27.00	63.23	21.67	24.00
Rill, gully formation	24.59	5.00	8.00	20.59	4.00	9.00	15.79	3.00	5.00	20.32	4.00	7.33
Siltation of tanks and reservoirs	0.61	0.09	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.03	0.06
Declining land value	33.13			30.88			33.33			32.45		

Table 3.34 Adoption of soil- and water-conservation practices among farmers of Garakahalli watershed

Practice	Marginal farmers			Small farmers			Large farmers			Pooled		
	Adopters	Expected crop loss by non–adoption, %		Adopters	Expected crop loss by non–adoption, %		Adopters	Expected crop loss by non–adoption, %		Adopters	Expected loss by non–adoption, %	
		Min	Max		Min	Max		Min	Max		Min	Max
Summer ploughing	156.00	10.00	15.00	63.00	12.00	17.00	18.00	13.00	18.00	237.00	11.67	16.67
Opening ridges and furrows	72.00	4.00	6.00	26.00	4.00	6.00	6.00	4.00	6.00	104.00	4.00	6.00
Contour bunding	36.00	2.00	3.00	11.00	1.00	2.00	3.00	1.00	2.00	50.00	1.33	2.33
Sowing across slope	147.00	14.00	19.00	60.00	16.00	20.00	18.00	16.00	21.00	225.00	15.33	20.00
Small-section bunds	39.00	2.00	3.00	12.00	2.00	3.00	3.00	2.00	3.00	54.00	2.00	3.00
Compartment bunds	36.00	2.00	3.00	13.00	2.00	3.00	3.00	1.00	2.00	52.00	1.67	2.67
Scooping	5.00	0.10	0.30	13.00	0.10	0.20	3.00	0.50	1.00	21.00	0.23	0.50
FYM application	163.00	34.00	45.00	65.00	34.00	44.00	18.00	36.00	46.00	246.00	34.67	45.00
Mulching	3.00	0.09	0.20	2.00	0.03	0.04	1.00	0.05	0.07	6.00	0.06	0.10
Silt/soil addition	79.00	6.00	10.00	29.00	6.00	9.00	11.00	11.00	17.00	119.00	7.67	12.00

Table 3.35 Reasons for non-adoption of soil- and water-conservation practices among the farmers of Garakahalli watershed

Reason	Marginal farmers		Small farmers		Large farmers		Pooled	
	Number	%	Number	%	Number	%	Number	%
Small holding	40	24.39	24	35.29	0	0.00	64	25.50
Practice is uneconomical	48	29.27	40	58.82	19	100	107	42.63
Practices come in the way of farm operations	0	0.00	0	0.00	0	0.00	0	0.00
Lack of funds	76	46.34	4	5.88	0	0.00	80	31.87

Table 3.38 Cost of cultivation, input-output relation for groundnut crop in Garakahalli watershed, data per hectare

Item	Unit	Marginal farmers			Small farmers			Large farmers			Pooled		
		Quantity	Value, Rs	%	Quantity	Value, Rs	%	Quantity	Value, Rs	%	Quantity	Value, Rs	%
Human labour													
Owned men	md	5.95	238.29	2.73	5.07	202.81	2.23	3.40	136.01	1.82	4.81	192.37	2.26
Owned women	wd	31.57	789.44	9.05	27.59	689.75	7.58	15.12	378.21	5.07	24.76	619.13	7.23
Hired men	md							1.58	63.47	0.85	0.53	21.16	0.28
Hired women	wd	18.90	472.51	5.42	36.6	915.16	10.05	30.41	760.43	10.19	28.64	716.03	8.55
Bullock labour													
Owned bullock	pd	8.91	1337.86	15.34	8.12	1218	13.38	5.33	800.83	10.73	7.45	1118.90	13.15
Hired bullock	pd				0.20	30.15	0.33	2.29	343.85	4.61	0.83	124.67	1.65
Seed material													
Owned seed	kg	51.73	1293.46	14.83	45.69	1142.32	12.55	63.30	1582.70	21.21	53.57	1339.49	16.20
Purchased seed	kg	25.79	644.83	7.39	26.53	663.46	7.29	19.85	496.40	6.65	24.06	601.56	7.11
Manures													
Owned manures	qtl	37.40	1871.17	21.46	35.20	1760.20	19.33	22.68	1134.70	15.21	31.76	1588.69	18.67
Purchased manures	qtl				1.00	51.94	0.57				0.33	17.31	0.19
Fertilizers													
Nitrogen	kg	22.58	193.44	2.22	28.84	241.45	2.65	18.78	157.24	2.11	23.40	197.38	2.33
Phosphorus	kg	56.12	897.86	10.30	72.87	1166.03	12.81	47.45	759.35	10.18	58.81	941.08	11.09
Potassium	kg	0.60	9.48	0.11							0.20	3.16	0.04
Interest on working capital (12.5% p.a.)	Rs		968.95	11.11		1011.60	11.11		829.02	11.11		936.52	11.11
Total operational cost	Rs		**8720.58**	100.00		**9104.47**	100.00		**7461.22**	100.00		**8428.76**	100.00
Yield of main product	qtl	7.61	6856.14	66.61	7.46	6714.52	67.98	7.22	6500.10	74.35	7.43	6690.25	69.64
Yield of by-product	Rs	30.52	3437.36	33.39	28.08	3163.13	32.02	19.92	2242.50	25.65	26.17	2947.66	30.36
GROSS RETURNS	Rs		10293.51	100.00		9877.66	100.00		8742.60	100.00		9637.92	100.00
NET RETURNS			**1572.93**			**773.19**			**1281.38**			**1209.17**	

Table 3.39 Yield/adoption gap analysis in groundnut in Garakahalli watershed, data per hectare

Item	Unit	Recom-mended	Marginal farmers			Small farmers			Large farmers			Pooled		
			Adoption	Yield/adoption gap		Adoption	Yield/adoption gap		Adoption	Yield/adoption gap		Adoption	Yield/adoption gap	
				Qty	%		Qty	%		Qty	%		Qty	%
FYM/compost	t	7.5	3.74	3.76	50.13	3.62	3.88	51.73	2.26	5.24	69.87	3.21	4.29	57.24
Biofertilizers	g	375		375.00	100.00		375.00	100.00		375.00	100.00	0.00	375.00	100.00
Nitrogen	kg	25	22.58	2.42	9.68	28.84	–3.84	–15.36	18.78	6.22	24.88	23.40	1.60	6.40
Phosphorus	kg	50	56.12	–6.12	–12.24	72.87	–22.87	–45.74	47.45	2.55	5.10	58.81	–8.81	–17.63
Potash	kg	25	0.60	24.40	97.60		25.00	100.00		25.00	100.00	0.20	24.80	99.20
Gypsum	kg	500	0.00	500.00	100.00		500.00	100.00		500.00	100.00	0.00	500.00	100.00
Seed rate	kg	110	77.52	32.48	29.53	72.22	37.78	34.35	83.15	26.85	24.41	77.63	32.37	29.43
P.P. chemicals														
Monocrotophos	L	2.45	0.00	2.45	100.00		2.45	100.00		2.45	100.00	0.00	2.45	100.00
Carbaryl	kg	7.5	0.00	7.50	100.00		7.50	100.00		7.50	100.00	0.00	7.50	100.00
Carbendizin	g	500	0.00	500.00	100.00		500.00	100.00		500.00	100.00	0.00	500.00	100.00
Potential yield														
Main product	qtl	9	7.61	1.39	15.44	7.46	1.54	17.11	7.22	1.78	19.78	7.43	1.57	17.44
By-product	t		3.05	–3.05		2.80	2.80		1.99	–1.99		2.61	–2.61	0.00

Table 3.40 Cost of cultivation, input-output relation for finger millet crop in Garakahalli watershed, data per hectare

Item	Unit	Marginal farmers			Small farmers			Large farmers			Pooled		
		Quantity	Value, Rs	%	Quantity	Value, Rs	%	Quantity	Value, Rs	%	Quantity	Value, Rs	%
Human labour													
Owned men	md	7.93	317.25	3.53	5.00	200.12	2.44	7.20	288.11	4.21	6.71	268.49	3.39
Owned women	wd	33.68	842.12	9.37	24.01	600.42	7.32	17.90	447.57	6.54	25.19	630.04	7.74
Hired men	md	0.37	15.00	0.17	0.02	1.14	0.01	0.00	0.00	0.00	0.13	5.38	0.06
Hired women	wd	31.58	789.58	8.78	45.51	1137.76	13.87	39.56	989.08	14.45	38.88	972.14	12.36
Bullock labour													
Owned bullock	pd	10.62	1593.74	17.73	7.63	1144.50	13.95	6.63	999.45	14.60	8.29	1245.90	15.42
Hired bullock	pd	0.91	136.57	1.52	0.25	38.79	0.47	0.86	129.30	1.89	0.67	101.55	1.29
Seed material													
Owned seed	kg	7.90	63.22	0.70	8.21	65.71	0.80	11.14	89.12	1.30	9.08	72.68	0.94
Purchased seed	kg	8.95	68.47	0.76	9.24	73.98	0.90	14.04	112.38	1.64	10.74	84.94	1.10
Manures													
Owned manures	qtl	50.44	2562.08	28.49	48.84	2443.27	29.78	30.60	1530.10	22.35	43.29	2178.48	26.87
Purchased manures	qtl	3.04	152.74	1.70							1.01	50.91	0.57
Fertilizers													
Nitrogen	kg	57.91	580.29	6.45	81.23	723.21	8.81	76.63	667.57	9.75	71.92	657.02	8.34
Phosphorus	kg	54.52	884.47	9.84	53.63	857.35	10.45	49.15	786.07	11.48	52.43	842.63	10.59
Potassium	kg	1.30	20.03	0.22	0.47	6.81	0.08	1.51	23.81	0.35	1.09	16.88	0.22
Interest on working capital	Rs		999.05	11.11		911.63	11.11		760.76	11.11		890.48	11.11
Total operational cost	Rs		**8991.47**	100.00		**8204.69**	100.00		**6846.86**	100.00		**8014.34**	100
Yield of main product	qtl	14.58	7291.17	71.39	13.04	6520.17	72.16	12.26	6134.50	78.21	13.293	6648.61	73.92
Yield of by product	qtl	25.96	2921.81	28.61	22.34	2515.95	27.84	15.16	1709.00	21.79	21.153	2382.25	26.08
GROSS RETURNS	Rs		10212.99	100.00		9036.12	100.00		7843.40	100.00		9030.84	100
NET RETURNS	Rs		**1221.52**			**831.43**			**996.54**			**1016.5**	

Table 3.41 Yield/adoption gap analysis in finger millet in Garakahalli watershed, data per hectare

Item	Unit	Recom-mended	Marginal farmers			Small farmers			Large farmers			Pooled		
			Adoption	Yield/adoption gap		Adoption	Yield/adoption gap		Adoption	Yield/adoption gap		Adoption	Yield/adoption gap	
				Qty	%		Qty	%		Qty	%		Qty	%
FYM/compost	t	7.5	5.34	2.16	28.80	4.88	2.62	34.93	3.06	4.44	59.20	4.43	3.07	40.98
Nitrogen	kg	50	57.91	–7.91	–15.82	81.23	–31.23	–62.46	76.63	–26.63	–53.26	71.92	–21.92	–43.85
Phosphorus	kg	40	54.52	–14.52	–36.30	53.63	–13.63	–34.08	49.15	–9.15	–22.88	52.43	–12.43	–31.08
Potash	kg	25	1.30	23.70	94.80	0.47	24.53	98.12	1.51	23.49	93.96	1.09	23.91	95.63
Seed rate	kg	11	16.85	–5.85	–53.18	17.45	–6.45	–58.64	25.18	–14.18	–128.91	19.83	–8.83	–80.24
P.P. chemicals														
Malathion	L	15		15.00	100.00		15.00	100.00		15.00	100.00	0.00	15.00	100.00
Carbendizin	g	500		500.00	100.00		500.00	100.00		500.00	100.00	0.00	500.00	100.00
Potential yield														
Main product	qtl	17.5	14.58	2.92	16.69	13.04	4.46	25.49	12.26	5.24	29.94	13.29	4.21	24.04
By-product	t	3.5	2.59	0.91	26.00	2.23	1.27	36.29	1.51	1.99	56.86	2.11	1.39	39.71

Table 3.42 Cost of cultivation, input-output relation for horsegram crop in Garakahalli watershed, data per hectare

Item	Unit	Marginal farmers			Small farmers			Large farmers			Pooled		
		Quantity	Value, Rs	%	Quantity	Value, Rs	%	Quantity	Value, Rs	%	Quantity	Value, Rs	%
Human labour													
Owned men	md	7.16	286.64	10.06	5.37	214.83	7.67	2.91	116.67	5.33	5.15	206.05	7.69
Owned women	wd	12.02	300.53	10.55	8.52	213.24	7.61	9.37	234.38	10.71	9.97	249.38	9.62
Hired men	md				0.62	25	0.89				0.21	8.33	0.30
Hired women	wd	3.47	86.96	3.05	3.01	75.27	2.69				2.16	54.08	1.91
Bullock labour													
Owned bullock	pd	6.41	961.8	33.76	7.1	1065.36	38.03	6.04	906.25	41.42	6.52	977.80	37.74
Hired bullock	pd	0.59	88.71	3.11				0.41	62.5	2.86	0.33	50.40	1.99
Seed material													
Owned seed	kg	13.97	139.79	4.91	16.26	162.64	5.81	10	100	4.57	13.41	134.14	5.09
Purchased seed	kg	7.4	74.01	2.60	6.74	67.41	2.41	17.08	170.83	7.81	10.41	104.08	4.27
Manures													
Owned manures	qtl	11.88	594.15	20.85	11.9	645	23.02	7.08	354.17	16.19	10.29	531.11	20.02
Purchased manures	qtl												
Fertilizers													
Nitrogen	kg				2.05	21.41	0.76				0.68	7.14	0.25
Phosphorus	kg												
Potassium	kg												
Interest on working capital	Rs		316.57	11.11		311.27	11.11		243.1	11.11		290.31	11.11
Total operational cost	Rs		2849.19	100		2801.43	100		2187.9	100		2612.84	100
Yield of main Product	qtl	4.62	2772.99	80.95	4.43	2659.04	83.08	4.06	2437.5	88.64	4.37	2623.18	84.22
Yield of by Product	Rs	8.68	652.47	19.05	7.2	541.45	16.92	4.16	312.5	11.36	6.68	502.14	15.78
GROSS RETURNS	Rs		3425.46	100		3200.49	100		2750	100		3125.32	100
NET RETURNS			576.27			399.06			562.1			512.48	

Table 3.43 Yield/adoption gap analysis in horsegram in Garakahalli watershed, data per hectare

Item	Unit	Recom-mended	Marginal farmers			Small farmers			Large farmers			Pooled		
			Adoption	Yield/adoption gap		Adoption	Yield/adoption gap		Adoption	Yield/adoption gap		Adoption	Yield/adoption gap	
				Qty	%		Qty	%		Qty	%		Qty	%
FYM/compost	t		1.18	–1.18		1.19	–1.19		0.70	–0.70		1.02	–1.02	0.00
Nitrogen	kg	25	0.00	25.00	100.00	2.05	22.95	91.80		25.00	100.00	0.68	24.32	97.27
Phosphorus	kg	38	0.00	38.00	100.00		38.00	100.00		38.00	100.00	0.00	38.00	100.00
Potash	kg	25	0.00	25.00	100.00		25.00	100.00		25.00	100.00	0.00	25.00	100.00
Seed rate	kg	25	21.37	3.63	14.52	23.00	2.00	8.00	27.08	–2.08	–8.32	23.82	1.18	4.73
Potential yield														
Main product	qtl	9	4.62	4.38	48.67	4.43	4.57	50.78	4.06	4.94	54.89	4.37	4.63	51.44
By–product	t		0.86			0.72			0.41			0.66		

Table 3.44 Cost of cultivation, input-output relation for banana crop in Garakahalli watershed, data per hectare

Item	Unit	Marginal farmers			Small farmers			Large farmers			Pooled		
		Quantity	Value, Rs	%	Quantity	Value, Rs	%	Quantity	Value, Rs	%	Quantity	Value, Rs	%
Human labour													
Owned men	md	229.39	8929.68	19.23	149.02	6506.94	12.26	149.71	6713.75	11.41	176.04	7383.46	14.30
Owned women	wd	24.35	608.98	1.31	55.97	1399.3	2.64	10	229.16	0.39	30.11	745.81	1.45
Hired men	md	48.39	1870.87	4.03	176.49	7018.05	13.22	166.87	6675.00	11.35	130.58	5187.97	9.53
Hired women	wd	26.3	657.55	1.42	17.29	432.29	0.81	33.42	835.67	1.42	25.67	641.84	1.22
Bullock labour													
Owned bullock	pd	14.34	2151.73	4.63	19.23	2885.41	5.44	21.91	2284.37	3.88	18.49	2440.50	4.65
Hired bullock	pd	11.22	1684.25	3.63	7.08	1062.5	2.00	9.01	234.37	0.40	9.10	993.71	2.01
Seed material													
Owned seed	kg												
Purchased seed	kg	1895.75	7583	16.33	2024.3	7513.9	14.16	1875	7500	12.75	1931.68	7532.30	14.41
FYM and green manure													
Owned manures	qtl	89.12	4457.54	9.60	114.16	5708.33	10.76	115.8	5791.66	9.84	106.36	5319.18	10.07
Purchased manures	qtl				8.32	416.67	0.79	113.12	5656.25	9.61	40.48	2024.31	3.47
Fertilizers													
Nitrogen	kg	130.49	2752.83	5.93	158.3	2836.20	5.34	211.52	2123.7	3.61	166.77	2570.91	4.96
Phosphorus	kg	206.01	6048.03	13.03	210.8	4720.7	8.90	291.25	4645.12	7.90	236.02	5137.95	9.94
Potassium	kg	139.98	1572.38	3.39	187.88	3669.4	6.91	361.06	6286.52	10.68	229.64	3842.77	7.00
Plant-protection chemicals	kg; L	16.04	1410.32	3.04	16.19	1459.19	2.75	19.35	1781.37	3.03	17.19	1550.29	2.94
Irrigation charges	Rs		1541.4			1541.4			1541.4				
Interest on working capital (12.5% p.a.)	Rs		5158.57	11.11		5896.28	11.11		6537.29	11.11		5864.05	11.11
Total operational cost	Rs		**46427.13**	100		**53066.56**	100		**58835.63**	100		52776.44	100
Yield of Main Product	qtl	180.23	126163.88	100	189.58	132708.33	100	175.73	123010.4	100	181.85	127294.20	100
Yield of By Product	qtl												
GROSS RETURNS	Rs		126163.88	100		132708.33	100		123010.4	100		127294.20	100
NET RETURNS	Rs		**79736.75**			**79642**			**64174.77**			**74517.76**	

Table 3.45 Yield/adoption gap analysis in banana in Garakahalli watershed, data per hectare

Item	Unit	Recom–mended	Marginal farmers			Small farmers			Large farmers			Pooled		
			Adoption	Yield/adoption gap		Adoption	Yield/adoption gap		Adoption	Yield/adoption gap		Adoption	Yield/adoption gap	
				Qty	%		Qty	%		Qty	%		Qty	%
FYM/compost	t	60	8.91	51.09	85.15	12.24	47.76	79.60	22.89	37.11	61.85	14.68	45.32	75.53
Nitrogen	kg	400	130.49	269.51	67.38	158.30	241.70	60.43	211.52	188.48	47.12	166.77	233.23	58.31
Phosphorus	kg	240	206.01	33.99	14.16	210.80	29.20	12.17	291.25	–51.25	–21.35	236.02	3.98	1.66
Potash	kg	500	139.98	360.02	72.00	187.88	312.12	62.42	361.06	138.94	27.79	229.64	270.36	54.07
Seed rate	kg	2225	1896.00	329.00	14.79	2024.30	200.70	9.02	1875.00	350.00	15.73	1931.77	293.23	13.18
Phorate	L	22.25	16.04	6.21	27.91	16.19	6.06	27.24	16.35	5.90	26.52	16.19	6.06	27.22
Yield – main product	t	25	18.02	6.98	27.92	18.95	6.05	24.20	17.57	7.43	29.72	18.18	6.82	27.28

Table 3.46 Cost of cultivation, input-output relation for rice crop in Garakahalli watershed, data per hectare

Item	Unit	Marginal farmers			Small farmers			Large farmers			Pooled		
		Quantity	Value, Rs	%	Quantity	Value, Rs	%	Quantity	Value, Rs	%	Quantity	Value, Rs	%
Human labour													
Owned men	md	54.85	2194.04	13.42	49.92	1680	9.56	27	1080.00	6.24	43.92	1651.35	9.74
Owned women	wd	82.12	2053.01	12.56	36.96	924.1	5.26	39.75	993.75	5.75	52.94	1323.62	7.85
Hired men	md	1.56	62.5	0.38	2.00	80	0.46	16.5	660.00	3.82	6.69	267.50	
Hired women	wd	52.35	1308.78	8.00	104.46	2611.6	14.86	101.5	2537.50	14.67	86.10	2152.63	12.51
Bullock labour													
Owned bullock	pd	11.05	1658.48	10.14	6.07	910.5	5.18	11	1650	9.54	9.37	1406.33	8.29
Hired bullock	pd												
Seed material													
Owned seed	kg	16.14	193.75	1.18	28.57	342.85	1.95	31	372	2.15	25.24	302.87	1.76
Purchased seed	kg	51.94	623.39	3.81	37.32	447.85	2.55	65	780	4.51	51.42	617.08	3.62
FYM and green manure													
Owned manures	qtl	51.28	2565.47	15.69	122	6100	34.72	64	3200	18.50	79.09	3955.16	22.97
Purchased manures	qtl	9.36	468.75	2.87							3.12	156.25	0.96
Fertilizers													
Nitrogen	kg	106.68	1469.69	8.99	91.1	1233.23	7.02	96.75	1563	9.04	98.18	1421.97	8.35
Phosphorus	kg	60.55	953.90	5.83	32.82	511.98	2.91	52.25	1121.6	6.48	48.54	862.49	5.08
Potassium	kg	30.55	473.90	2.90	12.25	182.83	1.04	40.25	605.3	3.50	27.68	420.68	2.48
Plant-protection chemicals	kg; L	0.54	274.8	1.68	0.814	389	2.21	1.07	492	2.84	0.81	385.27	2.25
Irrigation charges	Rs		300	1.83		300	1.71		300	1.73		300.00	1.76
Interest on working capital (12.5% p.a.)	Rs		1816.86	11.11		1952.30	11.11		1921.75	11.11		1896.97	11.11
Total operational cost	Rs		**16351.78**	100		**17570.71**	100		**17295.75**	100		**17072.75**	100
Yield of Main Product	qtl	25.19	15115.62	79.05	31.17	18707.14	83.54	31.5	18900	82.17	29.29	17574.25	81.59
Yield of By Product	qtl	40.04	4005.95	20.95	36.84	3686.34	16.46	41	4100	17.83	39.29	3930.76	18.41
GROSS RETURNS	Rs		19121.58	100		22393.48	100		23000	100		21505.02	100
NET RETURNS	Rs		**2769.80**			**4822.8**			**5704.25**			**4432.27**	

Table 3.47 Yield gap analysis in rice in Garakahalli watershed, data per hectare

Item	Unit	Recom-mended	Marginal farmers			Small farmers			Large farmers			Pooled		
			Adoption	Yield gap		Adoption	Yield gap		Adoption	Yield gap		Adoption	Yield gap	
				Qty	%		Qty	%		Qty	%		Qty	%
FYM/compost	t	7.5	6.06	1.44	19.20	12.20	–4.70	–62.67	6.40	1.10	14.67	8.22	–0.72	–9.60
Nitrogen	kg	100	106.68	–6.68	–6.68	91.10	8.90	8.90	96.75	3.25	3.25	98.18	1.82	1.82
Phosphorus	kg	50	60.55	–10.55	–21.10	32.82	17.18	34.36	52.25	–2.25	–4.50	48.54	1.46	2.92
Potash	kg	50	30.55	19.45	38.90	12.25	37.75	75.50	40.25	9.75	19.50	27.68	22.32	44.63
Seed rate	kg	62	68.08	–6.08	–9.81	65.89	–3.89	–6.27	96.00	–34.00	–54.84	76.66	–14.66	–23.64
P.P. chemicals														
Monocrotophos	L	1.56	0.54.	1.02	65.38	0.81	0.75	48.08	1.07	0.49	31.41	0.80	0.75	48.29
Potential yield														
Main product	qtl	45	25.19	19.81	44.02	31.17	13.83	30.73	31.50	13.50	30.00	29.29	15.71	34.92
By-product	t	0	4.00			3.68			4.10			3.93		

Table 3.48 Establishment cost per hectare of mulberry garden in Garakahalli watershed

Particulars	Marginal farmers		Small farmers		Large farmers		Pooled farmers	
	Value, Rs	Per cent	Value, Rs	Per cent	Value, Rs	Per cent	Value, Rs	Per cent
Land preparation								
Human labour	710.88	7.41	734.13	7.45	761.15	7.49	735.38	7.45
Bullock labour	1636.54	17.06	1690.08	17.15	1752.27	17.24	1692.963	17.15
Planting of cutting and maintenance								
Human labour	2856.16	29.77	2949.60	29.93	3058.13	30.09	2954.63	29.93
Bullock labour	555.90	5.80	574.08	5.82	595.21	5.86	575.06	5.83
Total labour cost	**5759.48**	60.04	**5947.89**	60.35	**6166.76**	60.68	**5958.04**	**60.36**
Inputs used								
Cuttings	379.02	3.95	391.42	3.97	405.82	3.99	392.08	3.97
Manuring	1461.35	15.23	1509.16	15.31	1564.69	15.40	1511.73	15.32
Fertilizers	283.84	2.96	293.13	2.97	303.92	2.99	293.63	2.97
Irrigation charges	1541.40	16.07	1541.40	15.64	1541.40	15.17	1541.40	15.62
Miscellaneous	167.61	1.75	173.09	1.76	179.46	1.77	173.38	1.76
Total input cost	**3833.22**	39.96	**3908.20**	39.65	**3995.29**	39.32	**3912.23**	**39.64**
Total establishment cost	**9592.70**	100.00	**9856.09**	100.00	**10162.05**	100.00	**9870.28**	**100.00**

Table 3.56 Annual maintenance cost per hectare of bearing coconut garden in Garakahalli watershed

Particulars	Cost in Rs			
	Marginal farmers	Small farmers	Large farmers	Pooled farmers
Labour cost				
Land preparation	254.57	391.01	424.8	356.79
Cleaning, widening (cover digging)	241.03	372.39	424.8	346.07
Manuring, fertilizer application	691.91	975.31	1133.11	933.44
Bunding	328.44	243.82	283.05	285.10
Fencing and maintenance	84.76	119.69	141.75	115.40
Watch and ward	95.35	391.01	424.8	303.72
Harvesting, collecting, transporting to house	746.95	1396.48	991.81	1045.08
Dehusking, bagging and transport to market	499.73	588.73	661.65	583.37
Subtotal	**2942.74**	**4478.44**	**4485.77**	**3968.98**
Materials cost				
Fencing material	0.00	0.00	577.22	192.41
Farmyard manure	6328.45	6925.02	6486.27	6579.91
Red earth	943.18	1534.58	1467.93	1315.23
Oilcakes	1034.45	928.08	1639.6	1200.71
Fertilizers	951.29	1297.85	2269.07	1506.07
Seedlings for replacement	883.34	250.00	350.00	494.45
Interest on working capital	1635.43	1895.49	2115.73	1882.22
Apportioned establishment cost	395.16	448.38	521.56	455.03
Subtotal	**12171.3**	**13279.4**	**15427.38**	13626.03
Grand total	**15114.04**	**17757.84**	**19913.15**	**17595.01**

Table 3.57 Annual yield and returns per hectare from ripened coconuts in Garakahalli watershed

Particulars	Unit	Marginal farmers	Small farmers	Large farmers	Pooled farmers
Yield					
Ripened nuts	Number	8752	9375	9150	9092.33
Average price realized per 1000 nuts	Rs	2500.00	2478.00	2495.00	2491.00
Returns obtained	Rs	21880.00	23231.25	22829.25	22646.83
By-products					
Dry fronds	Number	1500	1430	1520	1483.33
Average price realized per 1000 fronds	Rs	500.00	500.00	500.00	500.00
Returns	Rs	750.00	715.00	760.00	741.67
Gross returns	Rs	22630.00	23946.25	23589.25	23388.50
Total cost	Rs	13084.82	14908.27	16925.94	14973.01
Net returns	Rs	**9545.18**	**9037.98**	**6663.31**	**8415.49**

4. ENVIRONMENTAL VALUATION OF LAND RESOURCES

4.1 Production Function Analysis

The yield function per hectare was estimated separately for finger millet and groundnut.

The specific functional form used for finger millet and groundnut was

$$Y = a*X_1^{b1}*X_2^{b2}*X_3^{b3}*X_4^{b4}*X_5^{b5}*X_6^{b6}*X_7^{b7}*X_8^{b8}*X_9^{b9}*X_{10}^{b10}*X_{11}^{b11}*X_{12}^{b12}$$

or, in logarithmic form,

$$\ln Y = \ln a + b_1\ln X_1 + b_2\ln X_2 + b_3\ln X_3 + b_4\ln X_4 + b_5\ln X_5 + b_6\ln X_6 + b_7\ln X_7 + b_8\ln X_8 + b_9\ln X_9 + b_{10}\ln X_{10} + b_{11}\ln X_{11} + b_{12}\ln X_{12}$$

where a = intercept,

Y = yield (qtl),

X_1 = depth of the soil (cm),

X_2 = erosion of the soil (t/y),

X_3 = soil reaction (pH)

X_4 = FYM used (t),

X_5 = seed used (kg),

X_6 = nitrogen applied (kg),

X_7 = phosphorus applied (kg),

X_8 = potash applied (kg),

X_9 = men labour used (man days),

X_{10} = women labour used (woman days),

X_{11} = bullock labour used (pair days),

X_{12} = size of holding (ha).

The symbols b_1, b_2, b_3, b_4, b_5, b_6, b_7, b_8, b_9, b_{10}, b_{11} b_{12} represent the regression coefficients of the respective independent variables.

The marginal productivity of the respective inputs was calculated at the geometric mean levels of the output and input using the expression

$$\text{Marginal productivity of } X_i = Y(b_i / X_I)$$

where Y = geometric mean level of the output in quintals,

X_i = geometric mean level of the i^{th} independent variable,

b_i = regression coefficient of the i^{th} independent variable.

4.1.1 Production function analysis for finger millet

The resource productivity for finger millet calculated through production function ana-lysis is presented in Table 4.1. The regression coefficients were positive and significant for soil depth (0.311), farmyard manure applied (0.120), seed (0.053) nitrogen (0.028), potash (0.150) and women labour used (0.161), indicating the magnitude of yield change per additional unit of these inputs used over and above their present mean levels. The intercepts was positive (2.178) and significant and may be attributed to inherent capacity of the soil. The coefficient for soil erosion (–0.015) was negative and statistically non-significant, and those for soil gravel (–0.11) and size of holding (–0.117) were negative and statistically significant.

Table 4.1 Resource productivity in cultivation of finger millet and groundnut in Garakahalli watershed

Variable	Finger millet		Groundnut	
	Coefficient	*t* value	Coefficient	*t* value
Intercept (a)	2.178	2.93***	1.683	5.01***
Soil depth (X_1)	0.311	2.16**	0. 640	2.68***
Soil erosion (X_2)	–0.015	–0.18	–0.005	–0.08
Soil gravelliness (X_3)	0.110	2.19**	0.096	1.68**
Farmyard manure (X_4)	0.120	1.69**	0.063	1.68**
Seed (X_5)	0.053	3.15***	0.190	0.88
Nitrogen applied (X_6)	0.028	3.31***	–0.053	–1.63*
Phosphorus applied (X_7)	–0.053	2.87***	0.116	3.31***
Potash applied (X_8)	0.150	2.87***	0.034	1.63*
Men labour (X_9)	0.044	0.36	0.012	0.53
Women labour (X_{10})	0.161	2.19**	0.178	3.69***
Bullock labour (X_{11})	–0.071	–0.74	0.080	1.85**
Size of holding	–0.117	–2.90**	–0.073	–3.42***

*** Significant at 1 per cent level

** Significant at 5 per cent level

* Significant at 10 per cent level

	Finger millet	Groundnut
Sample size	195	45
Coefficient of multiple determination (R^2)	0.43	0.35
Price of output, Rs/qtl	500	1200

The regression coefficients resulting from this type of production function directly reflect the elasticity. Hence, positive and significant coefficients indicate the additional yield of finger millet per hectare that may be realized by using an additional unit of those resources over and above their present geometric mean levels. For example, for one unit increase in level of potash above the present level, the yield of finger millet would increase by 1.009 qtl/ha.

Marginal productivity refers to the contribution of a specific unit of input to the output and helps determination of the optimum level of input use. The data for finger millet in Table 4.2 reveal that, for every 1-cm increase in soil depth from the geometric mean depth (101.66 cm), yield would increase by 0.037 qtl/ha and

the gross returns by Rs.18.63. However, for every one per cent increase in erosion from the geometric mean level (5.17 t ha^{-1} y^{-1}), yield would decrease by 0.035 qtl/ha resulting in Rs 17.67 decrease in gross returns. An increase of one kg of potassium application would yield an additional return of Rs 504.70.

4.1.2 Production function analysis for groundnut crop

Data from the production function analysis for groundnut are also presented in Table 4.1. The regression coefficients were positive and statistically significant for soil depth (0.64), farmyard manure (0.063) and phosphorus (0.116). Thus these variables contributed significantly to groundnut yield and encourage use of additional quantities over and above their present geo-metric mean levels. However, the coefficient for size of land holding was negative (–0.073) and significant.

The marginal productivity of the inputs used in cultivation of groundnut is also presented in Table 4.2. For every unit increase in soil gravel content above the present geometric mean (15.61), groundnut yield would increase by 0.096 qtl *ceteris paribus*. This also means that the marginal productivity of soil gravel is 0.115 qtl, which adds Rs 137.63 to the gross income.

Similarly, the additional contributions from unit increases in application of farmyard manure, phosphorus and potash were 0.063, 0.116, and 0.034 qtl/ha, respectively. The marginal productivity of these inputs revealed that 0.136 qtl from farmyard manure, 0.41 qtl from phos-phorus and 0.604 qtl from potash would be the yield for each unit increase of these inputs over and above their present geometric mean levels. Their contribution to gross income would be Rs 163.38, Rs 49.56 and Rs 724.69, respectively.

4.2 Replacement Cost Approach for Estimation of Cost of Soil Erosion

Soil erosion is an indicator of land degradation. Soil erosion status was assessed in the watershed while studying, characterizing and mapping the soils. The three soil erosion classes used to estimate loss of soil nutrients by erosion per year in

Garakahalli watershed were defined with the corresponding annual losses of soil as slight (<5 t ha^{-1} y^{-1}), moderate (5–15 t ha^{-1} y^{-1}) and severe (15–40 t ha^{-1} y^{-1}).

Loss of soil by erosion also includes loss of soil organic matter. The loss per year was estimated in terms of the equivalent weight of farmyard manure. Nutrient losses due to soil erosion were estimated and the value worked out at prevailing market prices of the nutrients. The annual losses of nutrients through soil erosion estimated for each soil unit and for the entire watershed are presented in Table 4.3.

Soil organic matter. Annual soil organic matter loss from the soils ranged from a minimum of 16.38 kg/ha to a maximum of 524.10 kg/ha with a mean value of 69.62 kg/ha. Total annual soil organic matter loss for the watershed was 23143.28 kg, worth Rs.11571.64.

Nitrogen. Nitrogen loss ranged from 0.33 kg/ha to 3.51 kg/ha per year. The average annual loss worked out to 0.79 kg/ha. The total annual loss of nitrogen from the watershed was 302.77 kg, worth Rs.3157.94.

Phosphorus. Phosphorus loss ranged from 0.01 kg/ha to 0.36 kg/ha, and the average loss was 0.09 kg/ha. Total annual loss of phosphorus was 39.99 kg, worth Rs.639.92.

Potassium. The annual potassium loss ranged from 0.13 kg/ha to 2.71 kg/ha with an average loss of 0.71 kg/ha. The total annual potash loss estimated was 302.83 kg worth Rs. 2422.63.

Iron. The annual iron loss varied from 0.017 kg/ha to 0.655 kg/ha, with a mean of 0.078 kg/ha. The total annual loss of iron was 30.13 kg worth Rs.998.95.

Manganese. Annual manganese loss due to soil erosion ranged from 0.052 kg/ha to 0.873 kg/ha with a mean of 0.196 kg/ha. The total loss from the watershed was 73.93 kg, worth Rs.1091.25.

Copper. Loss of copper ranged from 0.00 kg/ha to 0.02 kg/ha per year with a mean of 0.01 kg/ha. About 2.45 kg of copper was lost annually from the watershed by soil erosion; its worth was Rs.36.13.

Zinc. Zinc loss was 0.00 kg/ha to 0.04 kg/ha per year. The total annual loss from the watershed was estimated at 2.35 kg, worth Rs.246.62.

The aggregate annual loss of soil organic matter and nutrients from the watershed as a whole was 23897.75 kg, with a value of Rs.20155.09.

4.3 Estimation of Cost of Misapplication of Nutrients

Misapplication of nutrients is grouped into Types I and II. Type I misapplication is the absolute difference between the regional blanket recommendation of nutrients and the balanced dose of nutrients for obtaining the potential yield as per soil test values (STCR). Type II misapplication is the difference between the levels actually added by the farmers and the nutri-ents required for the farmers' yield level (STCR).

4.3.1 Estimation of cost of misapplication of nutrients in finger millet

The data on level of nutrient application (excess or less) and the cost of misapplication practised by farmers for finger millet are presented in Table 4.4. The recommended fertilizer dose is 50–40–25 kg NPK/ha as against 46.06–14.35–19.76 kg NPK required for the regional targeted yield. The rate of misapplication found was 3.94–25.62–5.24 kg NPK/ha amounting to Rs. 492.94 misuse. On the other hand Type II misapplication (Fig. 4.1) showed that farmers in general were applying more N and P than required and less K, resulting in depletion of soil nutrient reserve. Type II misapplication varied with size group of farmers. The levels of nutrient application (kg NPK/ha) in the watershed for finger millet crop were 57.91–54.52–1.30, 81.23–53.63–0.47, and 76.63–49.15–1.51 kg NPK/ha by marginal, small and large farmers, respec-tively, as against 34.29–8.19–14.65, 27.45–6.26–12.65 and 25.73–4.60–10.38 kg NPK required for getting the present yields. The misapplication of nutrients (NPK) was highest (57.12 kg/ha) in marginal farmers followed by small farmers (46.36 kg/ha) and large farmers (40.71 kg/ha), valued at Rs. 880.94/ha (marginal), Rs. 1172.78/ha (large) and Rs. 122.49/ha (small farmers). Estimated loss in the watershed due to misapplication of nitrogen to finger millet was Rs 65771 (6.31 t), of

phosphorus Rs 115622 (7.23 t) and of potassium Rs (–)15074 [(–)1.88 t], giving a total of Rs 166318 (11.65 t).

4.3.1 Estimation of cost of misapplication of nutrients in groundnut

The data on level of nutrient application (excess or less) and the cost of misapplication practised by farmers for groundnut are presented in Table 4.5. The recommended nutrient dose is 25–50–25 kg NPK/ha as against (–)39.63–(–)216.43–(–115.58) kg NPK required for the regional targeted yield. The rate of misapplication found was 64.63–266.43–140.58 kg NPK/ha amounting to Rs. 6061.54 misuse. On the other hand Type II misapplication (Fig. 4.2) showed that farmers in general were applying more N, P and K than required, resulting in degradation of soil. Type II misapplication varied with size group of farmers. The levels of nutrient application (kg NPK/ha) in the watershed for groundnut crop were 22.58–56.12–0.60, 28.84–72.87–0.00, and 18.78–47.45–0.00 kg NPK/ha by marginal, small and large farmers, respectively, as against (–)48.67–(–)248.98–(–)129.79, (–)52.23–(–)232.49–(–)118.95, (–)46.75–(–)236.11–(–)137.04 kg NPK, respectively, required for getting the present yields. The misapplication of nutrients (NPK) was highest (540.21 kg/ha) in large farmers followed by marginal farmers (506.74 kg/ha) and small farmers (505.38 kg/ha). Estimated loss in the watershed due to misapplication of nitrogen to groundnut was Rs 36083.93 (3.46 t), of phosphorus Rs 178190.42 (11.14 t) and of potassium Rs38116.63 (4.76t), giving a total of Rs 252390.98 (19.36 t).

Table 4.4 Estimates of misapplication of nutrients to finger millet in Garakahalli watershed

	Nitrogen	Phosphorus	Potash	Total NPK
Regional recommendations (RR), kg/ha	50.00	40.00	25.00	115.00
STCR approach for RR-targeted yield, kg/ha	46.06	14.38	19.76	80.20
Type-I misapplication (RR–STCR), kg/ha	3.94	25.62	5.24	34.80
Type-I misapplication, Rs/ha	41.05	409.94	41.95	492.94
Farmers' present level of application (FP), kg/ha				
Marginal farmers	57.91	54.52	1.30	113.73
Small farmers	81.23	53.63	0.47	135.33
Large farmers	76.63	49.15	1.51	127.29
STCR approach for achieving FP-targeted yield, kg/ha				
Marginal farmers	34.29	8.19	14.65	57.12

	Nitrogen	Phosphorus	Potash	Total NPK
Small farmers	27.45	6.26	12.65	46.36
Large farmers	25.73	4.60	10.38	40.71
Type-II misapplication (FP–STCR), kg/ha				
Marginal farmers	23.62	46.33	–13.35	56.61
Small farmers	53.78	47.37	–12.18	88.97
Large farmers	50.90	44.55	–8.87	86.58
Type-II misapplication (FP–STCR), Rs/ha				
Marginal farmers	246.38	741.36	–106.80	880.94
Small farmers	560.98	757.99	–97.47	1221.49
Large farmers	530.91	712.87	–71.00	1172.78
Type-II misapplication for watershed				
Marginal farmers, kg	1554.12	3048.36	–878.28	3724.20
Small farmers, kg	3402.43	2996.89	–770.76	5628.56
Large farmers, kg	1349.41	1181.14	–235.26	2295.29
Total quantity for watershed, kg	**6305.96**	**7226.38**	**–1884.30**	**11648.04**
Total value for watershed, Rs	**65771.12**	**115622.12**	**–15074.38**	**166318.86**

Table 4.5 Estimates of misapplication of nutrients to groundnut in Garakahalli watershed

	Nitrogen	Phosphorus	Potash	Total NPK
Regional recommendations (RR), kg/ha	25.00	50.00	25.00	100.00
STCR approach for RR-targeted yield, kg/ha	–39.63	–216.43	–115.58	371.63
Type-I misapplication (RR–STCR), kg/ha	64.63	266.43	140.58	471.63
Type-I misapplication, Rs/ha	674.12	4262.82	1124.61	6061.54
Farmers' present level of application (FP), kg/ha				
Marginal farmers	22.58	56.12	0.60	79.30
Small farmers	28.84	72.87	0.00	101.71
Large farmers	18.78	47.45	0.00	66.23
STCR approach for achieving FP-targeted yield, kg/ha				
Marginal farmers	–48.67	–248.98	–129.79	427.44
Small farmers	–52.23	–232.49	–118.95	403.67
Large farmers	–46.75	–236.11	–137.04	419.89
Type-II misapplication (FP–STCR), kg/ha				
Marginal farmers	71.25	305.10	130.39	506.74
Small farmers	81.07	305.36	118.95	505.38
Large farmers	119.62	283.56	137.04	540.21
Type-II misapplication (FP–STCR), Rs/ha				
Marginal farmers	743.12	4881.57	1043.15	6667.83
Small farmers	845.59	4885.76	951.61	6682.96

	Nitrogen	Phosphorus	Potash	Total NPK
Large farmers	1247.65	4536.93	1096.28	6880.86
Type-II misapplication for watershed				
Marginal farmers, kg	511.56	2190.60	936.22	3638.39
Small farmers, kg	1402.56	5282.73	2057.86	8743.15
Large farmers, kg	1545.50	3663.57	1770.50	6979.57
Total quantity for watershed, kg	**3459.63**	**11136.90**	**4764.58**	**19361.11**
Total value for watershed, Rs	**36083.93**	**178190.42**	**38116.63**	**252390.98**

4.4 Estimation of Soil Potential Index in Garakahalli Watershed

The Soil Potential Index (SPI) is a numerical rating of a soil's relative suitability or quality and is expressed by

$$SPI = P – (CM+CL)$$

where, P = index of performance or yield as a locally established standard,

CM = index of costs of corrective measures to overcome or minimize the effect of soil limitations,

CL = index of costs resulting from continuing limitations.

Performance standard (P) for finger millet. Performance standard (P) for finger millet was established locally, assuming farmers' level of crop management and common practices. The yield standard was set based on the most productive soil having least soil limitations. In the present study soil unit ImB1 with 23.40 qtl/ha grain yield was considered the performance standard and served as basis for recognizing sub-standard soil performance in terms of both yield and additional costs required for correcting soil limitations. The level of crop management in achieving yield was measured in terms of cost, since consideration of cost is the most deciding factor in selection of any crop enterprise by farm households.

Corrective measures (CM) for finger millet. Corrective measures are an index of the additional costs above a defined standard (present level of cost of

cultivation). The only corrective measure required in the watershed was contour bunding to fight soil erosion. The cost incurred by the watershed development department worked out to Rs 3095/ha. The expected life span of contour bunds is 20 y. Thus the annual cost was Rs 154.75/ha. Where slope was 1–3 or 3–5 per cent the cost was doubled or quadrupled.

Continuing limitations (CL) for finger millet. continuing limitations are those that remain after corrective measures and could have adverse effects on economic returns (productivity value), environment (nutrient depletion and soil degradation due to imbalance in chemical-fertilizer use) and social values (shift from agriculture to other occupation, migration from rural to urban centres). The continuing limitation in Garakahalli watershed was low soil fertility.

Data on cost of corrective measures, continuing limitations of different soil units and corresponding soil potential ratings for finger millet are presented in Table 4.6. The soil limitations affecting soil suitability and crop yield in the watershed are texture, depth, drainage, soil fertility, acidity and erosion. Of these, texture and depth are not amenable to improvement. On the other hand, erosion and poor nutrient status limitations can be corrected by appropriate agronomic management measures such as contour bunding and application of additional ferti-lizer. The share of fertilizer inputs was the major annual investment. Fertile soils needed lower level of inputs (Rs 798.84 on Kg1hB1) than poor soils (Rs 177 on Gg1hE3St4).

In general, the soil potential rating assessment grouped the soils of the watershed into three categories, namely, medium, high and very high potential for growing finger millet based on current crop yield and management costs.

The SPR approach, on the other hand, grouping the watershed soils into 3 categories low, medium and high, appears to be more realistic and matching the ground reality. The present study reveals that suitability assessment by SPR is more rational than by the FAO framework. Crop yields are a better index for judging productive capacity of the soil than individual land/soil parameters or their combinations.

Performance standard (P) for groundnut. Performance standard (P) for groundnut was estab-lished locally, assuming farmers' level of crop management and common practices. The yield standard was set based on the most productive soil having least soil limitations. In the present study soil unit NiB1 with 10.40 qtl/ha groundnut yield was considered the performance standard and served as basis for recognizing sub-standard soil performance in terms of both yield and additional costs required for correcting soil limitations. The level of crop management in achieving yield was measured in terms of cost, since consideration of cost is the most deciding factor in selection of any crop enterprise by farm households.

Table 4.6 Soil potential ratings for finger millet in Garakahalli microwatershed

Soil unit	Area, ha	CM, Rs/ha	CL, Rs/ha	Total (CM + CL)		SPI = P – (CM + CL)		Rating
				Rs/ha	GE , qtl/ha	SPI	SPI, %	
Gg1hE3St4	1.75	774.00	1771.01	2545.01	5.09	18.31	78.25	Low
Gg1cE3St4	1.47	774.00	1701.47	2475.47	4.95	18.45	78.84	Low
Hg1hD2St4	2.41	619.00	1623.09	2242.09	4.48	18.92	80.84	Low
KhD2St3	5.65	619.00	1617.39	2236.39	4.47	18.93	80.89	Low
Jg1hD2St3	1.76	619.00	1608.17	2227.17	4.45	18.95	80.96	Low
Ig1hC1	1.16	464.00	1739.33	2203.33	4.41	18.99	81.17	Low
Hg2cD2St3	1.75	619.00	1579.16	2198.16	4.40	19.00	81.21	Low
Hg1cD2St4	4.80	619.00	1572.38	2191.38	4.38	19.02	81.27	Low
Hg2hD2St4	4.11	619.00	1569.74	2188.74	4.38	19.02	81.29	Low
KhD2	6.78	619.00	1561.06	2180.06	4.36	19.04	81.37	Low
Eg2cC2St4	2.04	464.00	1714.77	2178.77	4.36	19.04	81.38	Low
Gg2cD2St4-R	2.03	619.00	1551.08	2170.08	4.34	19.06	81.45	Low
IiC2	0.83	464.00	1648.49	2112.49	4.22	19.18	81.94	Low
Gg1hC1St3	1.22	464.00	1585.21	2049.21	4.10	19.30	82.49	Low
GbC2St3-R	3.98	464.00	1570.43	2034.43	4.07	19.33	82.61	Low
IbC1	2.63	464.00	1562.58	2026.58	4.05	19.35	82.68	Low
Dg1cC1	2.19	464.00	1541.76	2005.76	4.01	19.39	82.86	Low
Kg1hC2St4-R	4.50	464.00	1535.40	1999.40	4.00	19.40	82.91	Low
IcC1	1.91	464.00	1524.57	1988.57	3.98	19.42	83.00	Low
HmC1St3	2.16	464.00	1517.11	1981.11	3.96	19.44	83.07	Low
Gg2hC2St3	3.79	464.00	1509.56	1973.56	3.95	19.45	83.13	Low
Hg2iC1	2.31	464.00	1501.33	1965.33	3.93	19.47	83.20	Low
Ig2hC2St3	5.07	464.00	1496.02	1960.02	3.92	19.48	83.25	Low
Kg2hD2St4-R	2.88	619.00	1336.23	1955.23	3.91	19.49	83.29	Low

KiC1	4.49	464.00	1477.62	1941.62	3.88	19.52	83.40	Low
KbC2	5.97	464.00	1474.42	1938.42	3.88	19.52	83.43	Low
Lg1cD2St3	2.82	619.00	1301.10	1920.10	3.84	19.56	83.59	Low
JiB1	1.82	310.00	1585.04	1895.04	3.79	19.61	83.80	Low
Dg1bB1St3	1.29	310.00	1574.52	1884.52	3.77	19.63	83.89	Low
Ag2hD2St4	2.08	619.00	1241.56	1860.56	3.72	19.68	84.10	Low
KcC1	4.57	464.00	1395.48	1859.48	3.72	19.68	84.11	Low
FbB1	9.69	310.00	1545.51	1855.51	3.71	19.69	84.14	Low
IhB1	4.92	310.00	1541.78	1851.78	3.70	19.70	84.17	Low
HbB1	6.00	310.00	1540.20	1850.20	3.70	19.70	84.19	Low
NbB1	4.68	310.00	1540.13	1850.13	3.70	19.70	84.19	Low
Eg1hB1-R	5.33	310.00	1539.68	1849.68	3.70	19.70	84.19	Low
BmB1	3.65	310.00	1537.73	1847.73	3.70	19.70	84.21	Low
ImB1	6.47	310.00	1531.69	1841.69	3.68	19.72	84.26	Low
FiB1	10.85	310.00	1530.22	1840.22	3.68	19.72	84.27	Low
ImB2	2.08	310.00	1516.89	1826.89	3.65	19.75	84.39	Low
KhC1	3.12	464.00	1343.30	1807.30	3.61	19.79	84.55	Low
CcC2	3.17	464.00	1341.17	1805.17	3.61	19.79	84.57	Low
BcB1	3.70	310.00	1491.82	1801.82	3.60	19.80	84.60	Low
GcB1	8.76	310.00	1466.66	1776.66	3.55	19.85	84.81	Low
Dg1bB1	1.52	310.00	1460.13	1770.13	3.54	19.86	84.87	Low
Eg1iB1	5.87	310.00	1459.52	1769.52	3.54	19.86	84.88	Low
FhB1	2.02	310.00	1455.29	1765.29	3.53	19.87	84.91	Low
EmB1	2.37	310.00	1454.82	1764.82	3.53	19.87	84.92	Low
CiC1	3.26	464.00	1295.21	1759.21	3.52	19.88	84.96	Low
Hg1bB1	1.20	310.00	1444.39	1754.39	3.51	19.89	85.01	Medium
KmB1	16.59	310.00	1441.00	1751.00	3.50	19.90	85.03	Medium
Cg1hB1	5.15	310.00	1434.67	1744.67	3.49	19.91	85.09	Medium
DmB1	3.61	310.00	1430.20	1740.20	3.48	19.92	85.13	Medium
Eg1CB1St3	1.97	310.00	1427.85	1737.85	3.48	19.92	85.15	Medium
KhB1	43.77	310.00	1427.60	1737.60	3.48	19.92	85.15	Medium
GbB2	1.81	310.00	1422.84	1732.84	3.47	19.93	85.19	Medium
JhB1	7.08	310.00	1419.56	1729.56	3.46	19.94	85.22	Medium
HhB1	6.12	310.00	1419.12	1729.12	3.46	19.94	85.22	Medium
Lg1bC2St3	5.28	464.00	1255.73	1719.73	3.44	19.96	85.30	Medium
Gg1iC1	0.89	464.00	1255.21	1719.21	3.44	19.96	85.31	Medium
HcB1St3	3.73	310.00	1408.42	1718.42	3.44	19.96	85.31	Medium
McB1	0.97	310.00	1406.00	1716.00	3.43	19.97	85.33	Medium
KbB1	19.26	310.00	1405.79	1715.79	3.43	19.97	85.34	Medium

FcB1	15.44	310.00	1395.99	1705.99	3.41	19.99	85.42	Medium
MhB1	10.41	310.00	1388.39	1698.39	3.40	20.00	85.48	Medium
Hg1iC1	3.71	464.00	1215.92	1679.92	3.36	20.04	85.64	Medium
HcB1	2.41	310.00	1363.67	1673.67	3.35	20.05	85.70	Medium
CcB1	17.49	310.00	1361.83	1671.83	3.34	20.06	85.71	Medium
KcB1	22.77	310.00	1355.72	1665.72	3.33	20.07	85.76	Medium
CbB1	16.44	310.00	1345.67	1655.67	3.31	20.09	85.85	Medium
Cg2fB1	1.31	310.00	1339.88	1649.88	3.30	20.10	85.90	Medium
Hg1iB1	2.97	310.00	1332.22	1642.22	3.28	20.12	85.96	Medium
Hg1hB1	3.18	310.00	1324.81	1634.81	3.27	20.13	86.03	Medium
NcB1	10.82	310.00	1305.95	1615.95	3.23	20.17	86.19	Medium
IiB1	1.60	310.00	1259.31	1569.31	3.14	20.26	86.59	Medium
NhB1	3.89	310.00	1249.89	1559.89	3.12	20.28	86.67	Medium
Cg1bC1	2.70	464.00	1057.15	1521.15	3.04	20.36	87.00	Medium
NiB1	10.68	310.00	1186.48	1496.48	2.99	20.41	87.21	Medium
EbB1	4.29	310.00	1153.54	1463.54	2.93	20.47	87.49	Medium
Hg2bB1	1.73	310.00	1135.75	1445.75	2.89	20.51	87.64	Medium
ChB1	1.09	310.00	1071.43	1381.43	2.76	20.64	88.19	Medium
GbB1	1.33	310.00	1056.86	1366.86	2.73	20.67	88.32	Medium
IcB1	3.29	310.00	1043.02	1353.02	2.71	20.69	88.44	Medium
Kg1cB1	3.49	310.00	820.03	1130.03	2.26	21.14	90.34	High
Kg1hB1	2.54	310.00	798.84	1108.84	2.22	21.18	90.52	High

P	Potential yield	GE	Grain equivalent (23.40 qtl/ha)
CM	Corrective measure	CL	Continuing limitation

Corrective measures (CM) for groundnut cultivation. The only corrective measure required in the watershed was contour bunding to fight soil erosion. The cost incurred by the watershed development department worked out to Rs 3095/ha. The expected life span of contour bunds is 20 y. Thus the annual cost was Rs 154.75/ha. Where slope was 1–3 or 3–5 per cent the cost was doubled or quadrupled.

Continuing limitations (CL) for groundnut cultivation. The continuing limitations in Garaka-halli watershed were low soil fertility and acidity.

Data on cost of corrective measures, continuing limitations of different soil units and corresponding soil potential ratings for groundnut are presented in Table

4.7. The yield (10.40 qtl/ha) from soil unit NiB1 (very deep soils on <1% slope) with farmers' level of management was considered as yield performance standard. The soil limitations affecting soil suitability and crop yield in the watershed were texture, depth, drainage, soil fertility, acidity and erosion. Of these, texture and depth are not amenable to improvement. On the other hand, erosion and poor nutrient status limitations can be corrected by appropriate agronomic management measures such as contour bunding and application of additional fertilizer. The share of fertilizer inputs was the major annual investment. Fertile soils needed lower level of inputs (Rs 630.38 on NiB1) than poor soils (Rs 2833.86 on Hg1bB1).

Table 4.7 Soil potential ratings for groundnut in Garakahalli microwatershed

Soil unit	Area, ha	CM, Rs/ha	CL, Rs/ha	Total (CM + CL)		SPI = P – (CM + CL)		Rating
				Rs/ha	GE , qtl/ha	SPI	SPI, %	
Hg1bB1	1.20	310.00	2833.26	3143.26	2.62	7.78	74.81	Low
KhC1	3.12	464.00	2588.46	3052.46	2.54	7.86	75.54	Low
NbB1	4.68	310.00	2710.86	3020.86	2.52	7.88	75.79	Low
FiB1	10.85	310.00	2686.38	2996.38	2.50	7.90	75.99	Low
Eg1CB1St3	1.97	310.00	2604.78	2914.78	2.43	7.97	76.64	Low
CiC1	3.26	464.00	2428.39	2892.39	2.41	7.99	76.82	Low
IhB1	4.92	310.00	2486.46	2796.46	2.33	8.07	77.59	Low
BcB1	3.70	310.00	2441.58	2751.58	2.29	8.11	77.95	Low
Dg1cC1	2.19	464.00	1908.40	2372.40	1.98	8.42	80.99	Medium
NcB1	10.82	310.00	1996.86	2306.86	1.92	8.48	81.52	Medium
Hg1hB1	3.18	310.00	1982.33	2292.33	1.91	8.49	81.63	Medium
ImB2	2.08	310.00	1935.66	2245.66	1.87	8.53	82.01	Medium
Dg1bB1	1.52	310.00	1543.98	1853.98	1.54	8.86	85.14	Medium
HcB1St3	3.73	310.00	1440.67	1750.67	1.46	8.94	85.97	Medium
KmB1	16.59	310.00	1375.39	1685.39	1.40	9.00	86.50	Medium
Eg1iB1	5.87	310.00	1254.30	1564.30	1.30	9.10	87.47	Medium
KbC2	5.97	464.00	1018.96	1482.96	1.24	9.16	88.12	Medium
Gg1hE3St4	1.75	774.00	650.92	1424.92	1.19	9.21	88.58	Medium
Gg1cE3St4	1.47	774.00	630.38	1404.38	1.17	9.23	88.75	Medium
CcC2	3.17	464.00	865.70	1329.70	1.11	9.29	89.35	Medium
JhB1	7.08	310.00	966.95	1276.95	1.06	9.34	89.77	Medium
Gg1iC1	0.89	464.00	809.58	1273.58	1.06	9.34	89.80	Medium
Ag2hD2St4	2.08	619.00	630.38	1249.38	1.04	9.36	89.99	Medium
Gg2cD2St4-R	2.03	619.00	630.38	1249.38	1.04	9.36	89.99	Medium

Hg1cD2St4	4.80	619.00	630.38	1249.38	1.04	9.36	89.99	Medium
Hg1hD2St4	2.41	619.00	630.38	1249.38	1.04	9.36	89.99	Medium
Hg2cD2St3	1.75	619.00	630.38	1249.38	1.04	9.36	89.99	Medium
Hg2hD2St4	4.11	619.00	630.38	1249.38	1.04	9.36	89.99	Medium
Jg1hD2St3	1.76	619.00	630.38	1249.38	1.04	9.36	89.99	Medium
Kg2hD2St4-R	2.88	619.00	630.38	1249.38	1.04	9.36	89.99	Medium
KhD2	6.78	619.00	630.38	1249.38	1.04	9.36	89.99	Medium
KhD2St3	5.65	619.00	630.38	1249.38	1.04	9.36	89.99	Medium
Lg1cD2St3	2.82	619.00	630.38	1249.38	1.04	9.36	89.99	Medium
Hg1iC1	3.71	464.00	673.74	1137.74	0.95	9.45	90.88	High
Gg1hC1St3	1.22	464.00	661.77	1125.77	0.94	9.46	90.98	High
Cg1bC1	2.70	464.00	630.38	1094.38	0.91	9.49	91.23	High
Eg2cC2St4	2.04	464.00	630.38	1094.38	0.91	9.49	91.23	High
GbC2St3-R	3.98	464.00	630.38	1094.38	0.91	9.49	91.23	High
Gg2hC2St3	3.79	464.00	630.38	1094.38	0.91	9.49	91.23	High
Hg2iC1	2.31	464.00	630.38	1094.38	0.91	9.49	91.23	High
HmC1St3	2.16	464.00	630.38	1094.38	0.91	9.49	91.23	High
IbC1	2.63	464.00	630.38	1094.38	0.91	9.49	91.23	High
IcC1	1.91	464.00	630.38	1094.38	0.91	9.49	91.23	High
Ig1hC1	1.16	464.00	630.38	1094.38	0.91	9.49	91.23	High
Ig2hC2St3	5.07	464.00	630.38	1094.38	0.91	9.49	91.23	High
IiC2	0.83	464.00	630.38	1094.38	0.91	9.49	91.23	High
KcC1	4.57	464.00	630.38	1094.38	0.91	9.49	91.23	High
Kg1hC2St4-R	4.50	464.00	630.38	1094.38	0.91	9.49	91.23	High
KiC1	4.49	464.00	630.38	1094.38	0.91	9.49	91.23	High
Lg1bC2St3	5.28	464.00	630.38	1094.38	0.91	9.49	91.23	High
KbB1	19.26	310.00	702.60	1012.60	0.84	9.56	91.89	High
BmB1	3.65	310.00	630.38	940.38	0.78	9.62	92.46	High
CbB1	16.44	310.00	630.38	940.38	0.78	9.62	92.46	High
CcB1	17.49	310.00	630.38	940.38	0.78	9.62	92.46	High
Cg1hB1	5.15	310.00	630.38	940.38	0.78	9.62	92.46	High
Cg2fB1	1.31	310.00	630.38	940.38	0.78	9.62	92.46	High
ChB1	1.09	310.00	630.38	940.38	0.78	9.62	92.46	High
Dg1bB1St3	1.29	310.00	630.38	940.38	0.78	9.62	92.46	High
DmB1	3.61	310.00	630.38	940.38	0.78	9.62	92.46	High
EbB1	4.29	310.00	630.38	940.38	0.78	9.62	92.46	High
Eg1hB1-R	5.33	310.00	630.38	940.38	0.78	9.62	92.46	High
EmB1	2.37	310.00	630.38	940.38	0.78	9.62	92.46	High
FbB1	9.69	310.00	630.38	940.38	0.78	9.62	92.46	High

FcB1	15.44	310.00	630.38	940.38	0.78	9.62	92.46	High
FhB1	2.02	310.00	630.38	940.38	0.78	9.62	92.46	High
GbB1	1.33	310.00	630.38	940.38	0.78	9.62	92.46	High
GbB2	1.81	310.00	630.38	940.38	0.78	9.62	92.46	High
GcB1	8.76	310.00	630.38	940.38	0.78	9.62	92.46	High
HbB1	6.00	310.00	630.38	940.38	0.78	9.62	92.46	High
HcB1	2.41	310.00	630.38	940.38	0.78	9.62	92.46	High
Hg1iB1	2.97	310.00	630.38	940.38	0.78	9.62	92.46	High
Hg2bB1	1.73	310.00	630.38	940.38	0.78	9.62	92.46	High
HhB1	6.12	310.00	630.38	940.38	0.78	9.62	92.46	High
IcB1	3.29	310.00	630.38	940.38	0.78	9.62	92.46	High
IiB1	1.60	310.00	630.38	940.38	0.78	9.62	92.46	High
ImB1	6.47	310.00	630.38	940.38	0.78	9.62	92.46	High
JiB1	1.82	310.00	630.38	940.38	0.78	9.62	92.46	High
KcB1	22.77	310.00	630.38	940.38	0.78	9.62	92.46	High
Kg1cB1	3.49	310.00	630.38	940.38	0.78	9.62	92.46	High
Kg1hB1	2.54	310.00	630.38	940.38	0.78	9.62	92.46	High
KhB1	43.77	310.00	630.38	940.38	0.78	9.62	92.46	High
McB1	0.97	310.00	630.38	940.38	0.78	9.62	92.46	High
MhB1	10.41	310.00	630.38	940.38	0.78	9.62	92.46	High
NhB1	3.89	310.00	630.38	940.38	0.78	9.62	92.46	High
NiB1	10.68	310.00	630.38	940.38	0.78	9.62	92.46	High

P	Potential yield	GE	Grain equivalent (10.40 qtl/ha)
CM	Corrective measure	CL	Continuing limitation

In general, the soil potential rating assessment grouped the soils of the watershed into three categories medium, high and very high potential for growing groundnut based on current crop yield and management costs.

Comparison of groundnut yield with soil suitability class showed no logical correlation between suitability class and obtainable yield levels. However, soils with fewest limitations produced high yield and vice versa. The SPR approach, on the other hand, grouping the watershed soils into 3 categories (medium, high and very high) appears to be more realistic and matching the ground reality. The present study reveals that suitability assessment by SPR is more rational than by the FAO framework. Crop yields are a better index for judging productive capacity of the soil than individual land/soil parameters or their combinations.

4. 5 Valuation of Land Using Income Approach

The income approach to valuation requires estimates of income and expenses for calculating net income for each crop. The net income was capitalized at 11% (interest on fixed deposit) to arrive at the land value of each soil phase.

4.5.1 Land valuation for finger millet production system

The economic valuation of finger millet system on different soil units is presented in Table 4.8 and cost of cultivation ranged from a minimum of Rs 4691 on CbB1 to a maximum of Rs 7466 on NbB1 with a mean of Rs 5744 per hectare. Net returns ranged from a low of Rs 2000 per hectare on soil unit Lg1bC2St3 (very deep soil on 3–5% slope, with moderate erosion) to a high of Rs 6277 on soil unit ImB1 (moderately deep soil on 1–3% slope with slight erosion). Net returns from finger millet cultivation and soil depth were positively correlated (Fig. 4.3). Shallow soils (BcB1) fetched net returns of Rs 2746/ha compared to a maximum of Rs 5455/ha on very deep soil (KbB1) with a difference in net returns of Rs 2709/ha.

4.5.2 Land valuation for groundnut production system

Economic valuation of groundnut system on the soil units is presented in Table 4.9. Cost of cultivation ranged from a minimum of Rs 6150 on Eg1hB1-R to a maximum of Rs 10809 on HcB1 with a mean of Rs 8345 per hectare. Net returns ranged from a low of Rs 1054.74 per hectare on soil unit Fcb1 (deep soil on 1–3% slope, with slight erosion) to a high of Rs 5087 on soil unit KmB1 (very deep soil on 1–3% slope with slight erosion). Net returns from groundnut cultivation and soil depth were positively correlated (Fig. 4.4). Moderately shallow soils (CbB1) fetched net returns of Rs 2610/ha compared to a maximum of Rs 3222/ha on very deep soil (KbB1) with a difference in net returns of Rs 612/ha.

Table 4.8 Valuation of finger millet production system on different soil units in Garakahalli watershed

Soil unit	TCC, Rs/ha	TGR, Rs/ha	NR, Rs/ha	Land value, Rs/ha	B:C ratio
BcB1	**5896.00**	**8642.00**	**2746.00**	**24963.64**	**1.47**
CbB1	**4691.88**	**8762.32**	**4070.44**	**37004.01**	**1.87**
CcB1	5992.03	10864.00	4871.97	44290.63	1.81
CcC2	5411.00	8462.00	3051.00	27736.36	1.56
Cg1hB1	5421.00	10698.00	5277.00	47972.73	1.97
CiC1	5236.00	9684.00	4448.00	40436.36	1.85
Dg1bB1	5771.09	9504.97	3733.87	33944.28	1.65
EbB1	6163.60	10456.00	4292.40	39021.82	1.70
Eg1hB1-R	5815.90	9358.77	3542.88	32207.96	1.61
FbB1	**5650.07**	**10986.00**	**5335.93**	**48508.46**	**1.94**
FcB1	6034.28	9860.93	3826.65	34787.71	1.63
FiB1	5682.64	7735.56	2052.93	18662.98	1.36
GcB1	5642.00	9390.91	3748.91	34080.99	1.66
HcB1	6795.54	9600.00	2804.46	25495.09	1.41
HcB1st3	6145.30	9536.11	3390.82	30825.60	1.55
Hg1iB1	7496.53	10603.49	3106.95	28245.04	1.41
Hg2bB1	5810.94	9765.00	3954.06	35946.03	1.68
Hg2iC1	5805.11	8654.00	2848.89	25899.02	1.49
HhB1	6288.31	7842.86	1554.54	14132.23	1.25
HmC1st3	5012.30	7100.00	2087.70	18979.09	1.42
IcB1	6258.70	9536.11	3277.41	29794.64	1.52
ImB1	5423.00	11700.00	6277.00	57063.64	2.16
ImB2	5524.00	11700.00	6176.00	56145.45	2.12
JhB1	6325.95	8034.85	1708.90	15535.42	1.27
KbB1	**5234.00**	**10689.65**	**5455.65**	**49596.82**	**2.04**
KbC2	5411.13	6821.30	1410.17	12819.74	1.26
KcB1	5603.18	8901.77	3298.59	29987.18	1.59
KcC1	2905.69	10866.67	7960.98	72372.50	3.74
Kg1hB1	6214.82	9243.06	3028.24	27529.46	1.49
Kg1hC2st4-R	5032.28	7643.00	2610.72	23733.82	1.52
KhB1	5311.30	8975.83	3664.54	33313.96	1.69
KiC1	6211.76	9430.30	3218.54	29259.45	1.52
KmB1	5243.00	7863.24	2620.24	23820.39	1.50
Lg1bC2st3	5624.00	7624.00	2000.00	18181.82	1.36
MhB1	5523.00	8320.95	2797.95	25435.93	1.51
NbB1	7466.03	9764.00	2297.97	20890.67	1.31
NcB1	5127.75	9867.00	4739.25	43084.11	1.92
NhB1	5123.00	9984.00	4861.00	44190.91	1.95
NiB1	5617.21	10642.00	5024.79	45679.94	1.89

TCC = total cost of cultivation

TGR = total gross returns

NR = net returns

Value = capitalized value at 11 per cent

B:C ratio = benefit:cost ratio

Table 4.9 Valuation of groundnut production system on different soil units in Garakahalli watershed

Soil unit	TCC, Rs/ha	TGR, Rs/ha	NR, Rs/ha	Land value, Rs/ha	B:C ratio
CbB1	**8346.48**	**10956.78**	**2610.30**	**23729.95**	**1.31**
CcB1	8195.31	12332.06	4136.75	37606.84	1.50
Eg1hB1-R	6150.63	11007.46	4856.84	44153.05	1.79
FbB1	**8271.54**	**11209.86**	**2938.32**	**26712.02**	**1.36**
FcB1	10203.53	11258.26	1054.74	9588.52	1.10
GcB1	8969.51	10937.50	1967.99	17890.80	1.22
HbB1	8500.76	10625.00	2124.24	19311.25	1.25
HcB1	10809.35	12344.53	1535.18	13956.14	1.14
Hg1iB1	10256.12	12457.05	2200.93	20008.45	1.21
KbB1	**7864.50**	**11087.48**	**3222.98**	**29299.77**	**1.41**
KbC2	8193.20	10000.00	1806.81	16425.50	1.22
KcB1	7625.78	12150.30	4524.52	41131.99	1.59
Kg1hC2st4-R	9726.36	12106.78	2380.42	21640.16	1.24
KhB1	6920.66	11040.74	4120.08	37455.23	1.60
KmB1	6631.39	11718.75	5087.36	46248.75	1.77
MhB1	7655.60	11817.06	4161.46	37831.48	1.54
NbB1	8504.03	12233.25	3729.23	33902.05	1.44
NcB1	7484.54	12296.33	4811.80	43743.64	1.64
NiB1	8255.81	12483.15	4227.34	38430.34	1.51

TCC = total cost of cultivation

TGR = total gross returns

NR = net returns

Value = capitalized value at 11 per cent

B:C ratio = benefit:cost ratio

4.5.3 Land valuation for horsegram production system

The economic valuation of horsegram system on different soil units is presented in Table 4.10. Cost ranged from a minimum of Rs 1931 on FcB1 to a maximum of Rs 2760 on CiC1 with a mean cost of cultivation of Rs 2233 per hectare. Net returns ranged from a low of Rs 632 per hectare on soil unit CcB1 (moderately shallow soil on 1–3% slope, with slight erosion) to a high of Rs 1576 on soil unit KbB1 (very deep soil on 1–3% slope with slight erosion). Net returns from horsegram cultivation and soil depth were positively correlated (Fig. 4.5). Moderately shallow soils (CbB1) fetched net returns of Rs 1026/ha compared to a maximum of Rs 1527/ha on very deep soil (KbB1) with a difference in net returns of Rs 550/ha. The land value ranged from Rs 5745/ha to Rs 14335/ha.

Table 4.10 Valuation of horsegram production system on different soil units in Garakahalli watershed

Soil unit	TCC, Rs/ha	TGR, Rs/ha	NR, Rs/ha	Land value, Rs/ha	B:C ratio
CbB1	**2091.00**	**3117.79**	**1026.79**	**9334.44**	**1.49**
CcB1	2143.65	3192.24	1048.59	9532.64	1.49
Cic1	2760.00	3562.50	802.50	7295.45	1.29
FbB1	**2110.36**	**3649.46**	**1539.10**	**13991.84**	**1.73**
FcB1	1931.41	3161.76	1230.35	11185.04	1.64
Hg1iB1	2014.63	3422.44	1407.81	12798.25	1.70
HmC1st3	2354.32	2986.36	632.04	5745.82	1.27
IcB1	2707.14	3421.79	714.65	6496.81	1.26
ImB2	2113.25	3489.26	1376.01	12509.20	1.65
KbB1	**2165.34**	**3742.24**	**1576.90**	**14335.43**	**1.73**
KcB1	2342.15	3515.99	1173.84	10671.23	1.50
KhB1	2214.65	3667.24	1452.59	13205.34	1.66
NcB1	2211.11	3598.99	1387.88	12617.07	1.63
NiB1	2114.36	3591.00	1476.64	13424.00	1.70

TCC = total cost of cultivation
TGR = total gross returns
NR = net returns
Value = capitalized value at 11 per cent
B:C ratio = benefit:cost ratio

4.5.4 Land valuation for mulberry production system

The economic valuation of mulberry system on different soil units is presented in Table 4.11 and cost of cultivation ranged from a minimum of Rs 10185 on KbB1 to a maximum of Rs 15936 on NcB1 with a mean of Rs 11523 per hectare. Net returns ranged from a low of Rs 9837 per hectare on soil unit Lg1bC2St3 (very deep soil on 3–5% slope, with moderate erosion) to a high of Rs 48334 on soil unit NbB1 (very deep soil on 1–3% slope with slight erosion). Net returns from mulberry cultivation and soil depth were positively correlated (Fig. 4.6). Moderately shallow soils (CbB1) fetched net returns of Rs 25929/ha compared to a maximum of Rs 35708/ha on very deep soil (KbB1) with a difference in net returns of Rs 9779/ha. Soil gravel and net returns indicated inverse relationship. The net returns of mulberry on non-gravelly soils were Rs 30034/ha compared to Rs 11292/ha on gravelly soils(>35 %), the difference being Rs. 18742/ha. The

comparison (Fig 4.4) demonstrates the adverse effect of soil gravel. The land value ranged from Rs 89434/ha to Rs 439401/ha.

Table 4.11 Valuation of mulberry production system on different soil units in Garakahalli watershed

Soil unit	TCC, Rs/ha	TGR, Rs/ha	NR, Rs/ha	Land value, Rs/ha	B:C ratio
CbB1	**10658.23**	**36587.13**	**25928.90**	**235717.27**	**3.43**
CcB1	11409.44	38459.35	27049.91	245908.27	3.37
Dg1bB1	11256.35	31250.00	19993.65	181760.45	2.78
EmB1	11263.00	31948.05	20685.05	188045.93	2.84
FbB1	**10336.82**	**39786.54**	**29449.72**	**267724.75**	**3.85**
GcB1	10534.00	40568.65	30034.65	273042.27	3.85
HbB1	10286.36	28654.00	18367.64	166978.55	2.79
HcB1	11243.21	32461.00	21217.79	192889.00	2.89
Hg1iC1	10998.32	28965.00	17966.68	163333.45	2.63
Hg2iC1	10362.52	21654.00	11291.48	102649.82	2.09
KbB1	**10188.09**	**45896.35**	**35708.26**	**324620.54**	**4.50**
KcB1	12356.34	43689.64	31333.30	284848.18	3.54
Kg1hB1	12365.46	23500.00	11134.54	101223.09	1.90
KhB1	10720.05	48234.15	37514.10	341037.30	4.50
KmB1	11523.12	35462.00	23938.88	217626.18	3.08
Lg1bC2st3	11708.48	21546.32	9837.84	89434.88	1.84
MhB1	12365.21	33714.29	21349.08	194082.51	2.73
NbB1	12851.77	61185.90	48334.13	439401.17	4.76
NcB1	15936.04	43253.54	27317.50	248340.87	2.71
NiB1	12104.61	48937.50	36832.89	334844.43	4.04

TCC = total cost of cultivation

TGR = total gross returns

NR = net returns

Value = capitalized value at 11 per cent

B:C ratio = benefit:cost ratio

4.5.5 Land valuation for banana production system

Economic valuation of banana system on different soil units is presented in Table 4.12. Cost of cultivation ranged from a minimum of Rs 25128 on Kg1hB1 to a maximum of Rs 36516 on NcB1 with a mean of Rs 29776 per hectare. Net returns ranged from a low of Rs 70872 per hectare on soil unit CbB1 (moderately deep soil on 1–3% slope, with slight erosion) to a high of Rs 92483 on soil unit NcB1 (very deep soil on 1–3% slope with slight erosion). Net returns from banana cultivation and soil depth were positively correlated (Fig. 4.7). Moderately shallow soils (CbB1) fetched net returns of Rs 70872/ha compared to a maximum of Rs 83770/ha on very deep soil (KbB1) with a difference in net returns of Rs 12895/ha.

Table 4.12 Valuation of banana production system on different soil units in Garakahalli watershed

Soil unit	TCC, Rs/ha	TGR, Rs/ha	NR, Rs/ha	Land value, Rs/ha	B:C ratio
CbB1	25128.00	96000.00	70872.00	644290.91	3.82
FiB1	28756.55	108462.00	79705.45	724595.00	3.77
GcB1	27290.00	104628.00	77338.00	703072.73	3.83
KbB1	28730.00	112500.00	83770.00	761545.45	3.92
KcB1	30887.50	114034.09	83146.59	755878.11	3.69
Kg1hB1	25755.09	105750.00	79994.91	727226.45	4.11
KhB1	33508.24	116742.86	83234.62	756678.34	3.48
KmB1	33044.00	112682.00	79638.00	723981.82	3.41
NbB1	27430.09	107718.75	80288.66	729896.88	3.93
NcB1	36516.60	129000.00	92483.40	840758.18	3.53
NiB1	30496.34	111375.00	80878.66	735260.57	3.65

TCC = total cost of cultivation
TGR = total gross returns
NR = net returns
Value = capitalized value at 11 per cent
B:C ratio = benefit:cost ratio

4.5.1 Land valuation for coconut production system

Economic valuation of coconut system on different soil units is presented in Table 4.13. Cost of cultivation ranged from a minimum of Rs 11293 on JhB1 to a maximum of Rs 16637 on Hg2iC1 with a mean of Rs 14248 per hectare. Net

returns ranged from a low of Rs 8472 per hectare on soil unit CbB1 (moderately deep soil on 1–3% slope, with slight erosion) to a high of Rs 25060 on soil unit NhA1 (very deep soil on 1–3% slope with slight erosion). Net returns from coconut cultivation and soil depth were positively correlated (Fig. 4.8). Moderately deep soils (CbB1) fetched net returns of Rs 8472/ha compared to a maximum of Rs 25060/ha on very deep soil (NhB1) with a difference in net returns of Rs 16588/ha.

Table 4.13 Valuation of coconut production system on different soil units in Garakahalli watershed

Soil unit	TCC, Rs/ha	TGR, Rs/ha	NR, Rs/ha	Land value, Rs/ha	B:C ratio
CbB1	**14979.09**	**23451.30**	**8472.21**	**77020.06**	**1.57**
CcB1	11405.00	22654.23	11249.23	102265.73	1.99
Dg1bB1	12407.80	24456.32	12048.52	109532.00	1.97
Eg1hB1-R	13520.42	24653.21	11132.79	101207.21	1.82
FiB1	**16063.28**	**26875.32**	**10812.05**	**98291.32**	**1.67**
GcB1	13658.03	29250.00	15591.98	141745.23	2.14
HbB1	13237.50	27634.35	14396.85	130880.45	2.09
HcB1	16241.67	31250.00	15008.33	136439.39	1.92
Hg1iC1	14974.08	31632.65	16658.58	151441.62	2.11
Hg2iC1	16637.23	27972.97	11335.75	103052.25	1.68
JhB1	11293.86	29763.64	18469.77	167907.02	2.64
KbB1	**12817.45**	**32343.75**	**19526.30**	**177511.82**	**2.52**
KcB1	13909.43	31218.75	17309.33	157357.50	2.24
KcC1	12539.70	34562.32	22022.62	200205.64	2.76
Kg1hB1	13591.40	31544.89	17953.49	163213.55	2.32
KhB1	16063.22	33097.22	17034.00	154854.53	2.06
KmB1	16462.50	33750.00	17287.50	157159.09	2.05
Lg1bC2st3	15231.00	33437.50	18206.50	165513.64	2.20
MhB1	15108.47	33527.78	18419.31	167448.23	2.22
NbB1	16131.93	35652.95	19521.03	177463.86	2.21
NcB1	14768.25	29051.21	14282.95	129845.04	1.97
NhB1	12815.00	37875.00	25060.00	227818.18	2.96
NiB1	13865.00	30060.61	16195.61	147232.78	2.17

TCC = total cost of cultivation
TGR = total gross returns
NR = net returns
Value = capitalized value at 11 per cent
B:C ratio = benefit:cost ratio

4.6 Optimum Land-use Plans for Garakahalli Watershed

Present cropping and input-use pattern. In the existing cropping pattern in Garakahalli watershed farm households were growing finger millet (145.22 ha rainfed and 10.34 ha irrigated), groundnut (37.40 ha), horsegram (22.63 ha) coconut (28.4 ha), rice (7.45 ha), banana (17.54 ha) and mulberry (22.12 ha), which accounted for 50.73, 12.2, 7.38, 2.43, 7.21, 5.72 and 9.27 per cent, respectively, of the total cultivated area of the watershed (Table 4.14).

The quantities of various inputs used under the existing cropping pattern were 13580 qtl FYM, 3089 pair-days bullock labour, 12111 days men labour, 18849 days women labour, 22028 kg N, 17745 kg P and 6977 kg K. The cash expenses incurred for these inputs amounted to Rs 2860781. The net income realized was Rs 3980494. Based on data on availability of own funds (cash) it was estimated that around Rs 28.61 lakhs short-term loan was used.

Analysis of the data by linear programming technique. The information collected from the watershed farmers was tabulated and analysed using linear programming technique to draw inferences on the nine objectives set forth in the study. The results of the analysis are presented in Table 4.15 in the form of normative land-use plans for the watershed. Table 4.16 gives data on input use and net income under the different models.

4.6.1 Model I: maximization of net income

The optimum plan under maximization of net income as an objective recommended cultivation of finger millet on a larger area of 200 ha against the current area of 155.56 ha. The area recommended for finger millet on series B was 7.35 ha, on C 50.61 ha, on E 21.87 ha, on H 51.47 ha, on I 29.95 ha, on J 10.66 ha, on K 19.99 ha and on series L 8.10 ha. The minimum finger millet area (200 ha) was specified for meeting the food requirement in all the models.

The area under mulberry, which was 22.12 ha under existing cropping pattern, increased to 145.11 ha to be grown on soil series K (123.49) and series N (21.62). The area under banana increased from 17.54 ha under existing cropping pattern to 65.03 ha to be grown on soil series F (38 ha) and G (27.03

ha). The coconut crop area remained unchanged at 28.44 ha to be cultivated as is being done now on soil series D (8.61ha), M (11.38 ha) and N (8.45 ha). The other crops, namely, groundnut and horsegram were not recommended in the plan. The total area recommended for cultivation was 438.58 ha to realize a net income of Rs. 94,91,343.53. This would require costs of Rs 4,08,666.65 for the purpose of 7710.79 bullock-pair days, 28,689 men labour days, 30,296.62 women labour days, 5444.69 qtl FYM, 23,608.17 kg nitrogen, 1648.53 kg phosphorus and 13541.34 kg potash. This model suggests the necessity of Rs 10.4 lakhs of crop loan over and above the availability of Rs 30.45 lakhs of owned funds.

There was no recommendation of fallow land in this model.

4.6.2 Model II: minimization of cost

The optimum plan with minimization of cost as objective recommended changes in area under finger millet crop on soil series E, F, G, J and K, but did not change area on soil series B, C, I and L as well as total area (200 ha). However there was decrease in area on series H from 51.47 to 38.96 ha. The optimization model with cost minimization as main focus allocated 200 ha under finger millet, 22.12 ha under mulberry (8.61 on soil series D, 2.13 on H and 11.38 on N) and 28.44 ha of coconut on soil series N. This model recommended the entire coconut area to be on soil series N unlike in Model I where it was on series D, M and N. The mulberry area had been reduced to a minimum of 22.12 ha from 145.11 ha of model I and the entire area (65.03 ha) under banana in model I was removed to minimize cost. It can be observed that the reduced area under mulberry and banana has been recommended to be left fallow (188.02 ha). The cropping pattern in this model would provide a net income of Rs 19,07,833.27 (lower than that under maximization of net income and also under the existing pattern) with cost of Rs 13,16,168.99. All the inputs were lower than in Model I. This model indicated a surplus of Rs 17.3 lakhs of owned funds.

4.6.3 Models III, IV, V: minimization of bullock, men, women labour

(a) Model III—minimization of bullock labour. The cropping pattern obtained when the model for minimization of bullock labour was applied did not show any change in the total area under finger millet, mulberry and coconut from the pattern under Model II. However there were small changes in the area under individual soil series. These marginal changes would be reflected in the net income and cost associated. The area under finger millet on soil series K increased to 123.95 ha from the 19.99 ha of model I and 0 ha under model II. Mulberry crop was recommended for 22.12 ha by this model (14.92 ha on series C and 7.2 ha on series D). The area under coconut, which was on series N in model II, has been shifted to series D (1.41 ha) and series G (27.03 ha). Net income under this model would be Rs 18,03,622.96, and the costs incurred would be Rs 13,86,386.74. This model also recommended 188.02 ha be left fallow on different soil series.

(b) Model IV—minimization of men labour. The cropping pattern obtained with Model IV (minimization of men-labour) compared to that with Model III calls for adjustments in area under finger millet on series B, C, F, H, J, L, M, and N, while coconut area (28.44 ha) is allocated on soil series C (1.41 ha) and G (27.03 ha). The mulberry area (22.12 ha) is suggested on soil series D (8.16 ha) and H (13.51ha). Fallowing is recommended for 188.02 ha, as in the previous two models. Under this cropping pattern under minimization of men labour the farmers of the watershed would realize a net income of Rs 15,72,060.49 with a total cost of Rs 13,32,427.74.

(c) Model V—minimization of women-labour. The optimum cropping pattern under Model V (minimization of women-labour) showed net income of Rs 17,24,317.00 with the cost incurred at Rs 1477429.45. The model suggested finger millet, mulberry and coconut to be on 200 ha, 22.12 ha and 28.44 ha, respectively. In order to reduce the employment of women-labour the model suggested 188.02 ha to be left fallow.

4.6.4 Model VI: maximization of FYM use

The cropping pattern with maximization of FYM use suggested the largest area (388.02 ha) under finger millet, allocated among soil series B (7.35 ha), C (50.61 ha), D (98.31 ha), E (21.87 ha), F (33.95 ha), H 951.47 ha), I (29.95 ha), J (10.66 ha), K (143.48 ha) and N (30.07 ha). Mulberry was recommended on soil series G (2.64 ha), L (98.10 ha) and M (11.38 ha), and coconut on F (4.05 ha), and G (24.39 ha). The entire cultivable area of 438.58 ha has been allocated for cropping, without suggesting any fallow land.

The net income would be Rs 2106058.91 with a cost of Rs 24,21,505.68. The FYM purchased was the highest (6879.54 t).

4.6.5 Model VII: minimization of nitrogen use

The optimization model for reducing the level of use of nitrogen recommended finger millet, mulberry and coconut to be on an area of 200, 22.12 and 28.44 ha, respectively. Finger millet was allocated to soil series B (7.3 ha), C (50.61 ha), D (8.61 ha), E (21.87 ha), F (15.88 ha), G (27.03 ha), H (51.47 ha) and I (17.18 ha), all of the mulberry to soil F and coconut to soil J (10.66 ha), K (6.40 ha) and M (11.38 ha).

4.6.6 Model VIII: minimization of phosphorus use

Application of the model for minimization of phosphorus use resulted in the same area under finger millet (200 ha) as in the other minimization models. This area was distributed on series B (7.3 ha), C (50.61 ha), D (8.61 ha), E (21.87), F (38 ha), G (27.03 ha), H (40.73 ha) and L (5.80 ha). Mulberry was allocated to series H (10.74 ha) and M (11.38 ha) and coconut to series J (10.66 ha) and K (17.78)). The uniqueness of this optimization model is that it recom-mended horsegram on 125.70 ha of soil series K. No other model recommended horsegram, though in the existing pattern it is being grown on 23.63 ha. The net income realizable would be Rs 1949285.90 at a cost of Rs 1674124.12. The FYM purchased was the highest (6879.54 t) of all the models. The fallow land recommended was 62.32 ha.

4.6.5 Model IX: minimization of potash use

The optimization model for reducing the level of use of potash recommended finger millet on all soil series from B to N excepting series E, H and K. Groundnut has been allocated to 143.48 ha of soil series K, mulberry to series E (21.87 ha) and series F (0.25 ha). All the area for coconut (24.44 ha) was allocated to series H. The net income calculated was Rs 2114128.61 and the cost of Rs 2372415.28. The model suggested a smaller area under fallow (44.54 ha) than the other models. The cropping pattern, inputs, cost and net income calculated under the models for minimization of N use and of K use were the same. The cost was Rs 1392418.60 and the net income Rs1881937.76.

All nine optimization models recommended large area under finger millet, as farmers of Garakahalli watershed are presently following subsistence agriculture, that is, self-dependence for food requirement from their own farm land. The areas under mulberry remained unaltered in all the models except under that for maximization of net income where the area recommended for this crop was 145.11 ha. However the areas on specific soil series varied between models.

4.6.7 Pay-off matrix for different objectives in Garakahalli watershed

The results of the models concerned with the nine objectives for the cultivable land under different soil series of Garakahalli watershed are presented in Table 4.17. The elements of the matrix were derived by optimizing one objective at a time and then computing the corresponding magnitude of the rest of the objectives in that optimum plan. The value elements in each column of the table (pay off matrix and the ideal points) indicate the level of achievement of the other objectives when one objective was optimized (maximized or minimized as the case may be). For example, the first column shows that the maximum net income of Rs 94,91,343.53 was associated with a cost of Rs 40,86,667.65 for 7710.79 bullock-pair days, 28,689.17 men-labour days, 30,296.02 women-labour days, 5455.09 t FYM, 23,608.49 kg N, 16,489.53 kg P and 13,541 kg K plus the seed costs, etc.

Hence, finger millet is to be grown on 7.53 ha of series B, 50.61 ha of C, 21.87 ha of E, 51.47 ha of H, 29.95 ha of I, 10.66 ha of J, 19.99 ha of K and 8.10 ha of series L (total 200 ha), mulberry on 145.11 ha (123.4 ha of series K and 21.62 ha of series N), banana on 65.03 ha (38 ha of series F and 27.03 ha of series G) and coconut on

28.44 ha (11.38 ha of series M and 8.45 ha of series N) to realize an optimum (maximum) income of Rs 94,91,343.53.

Similarly, the data in the pay-off matrix of each row shows the optimization of one objective and the related levels of other objectives. To illustrate, the minimization of cost in row 2, column 2 reflects the optimum (minimum) costs of Rs 13,16,168.99 that would bring under cultivation 250.56 ha out of a cultivable area of 438.58 ha in Garakahalli watershed with different crops such as finger millet on 200 ha distributed on series B (7.35 ha), C (50.61 ha), F (38 ha), G (27.03 ha), H (38.46 ha), I (29.95 ha) and L (8.10 ha), mulberry on 22.12 ha (8.61 ha of D, 2.13 ha of H and 11.38 ha of M) and coconut on 28.44 ha of series N, and allow 188.02 ha of fallow land. Although this cropping pattern minimized the costs, the net income was only Rs 19,07,833.27, very much lower than that under the maximization of income model (Model I).

It is observed from the table that when one objective was optimized, the other objectives were either underachieved or exceeded. For example, when the net income was maximized (optimized), the costs were higher at Rs 40,86,667.65 (Model I) than what would have been with minimization of cost as sole objective (Rs 13,16,168.99). Similarly, when minimization (optimi-zation) of cost was achieved, the net income concomitantly reduced to Rs 19,07,833.27 (from Rs 94,91,343.53 of maximization of income model).

The elements in the main diagonal of the pay-off matrix are referred to as the ideal points (objective functional value of each plan) or an ideal plan combining all the nine objectives for the Garakahalli watershed as a whole. All the nine objectives are optimized and the ideal points are listed in the last row of the table, which provides Rs 94,91,343.63 net income and Rs 13,16,168.99 cost to cover 3626.52 bullock-pair, 4652.63 men-labour and 11,083 women-labour days, with application of 6878.54 t FYM (5,489.54 tons of FYM to be purchased from outside over and above their own quantity of 1,389 tons), 8,063.04 kg N, 5109.88 kg P and 9.07 kg K plus seed cost.

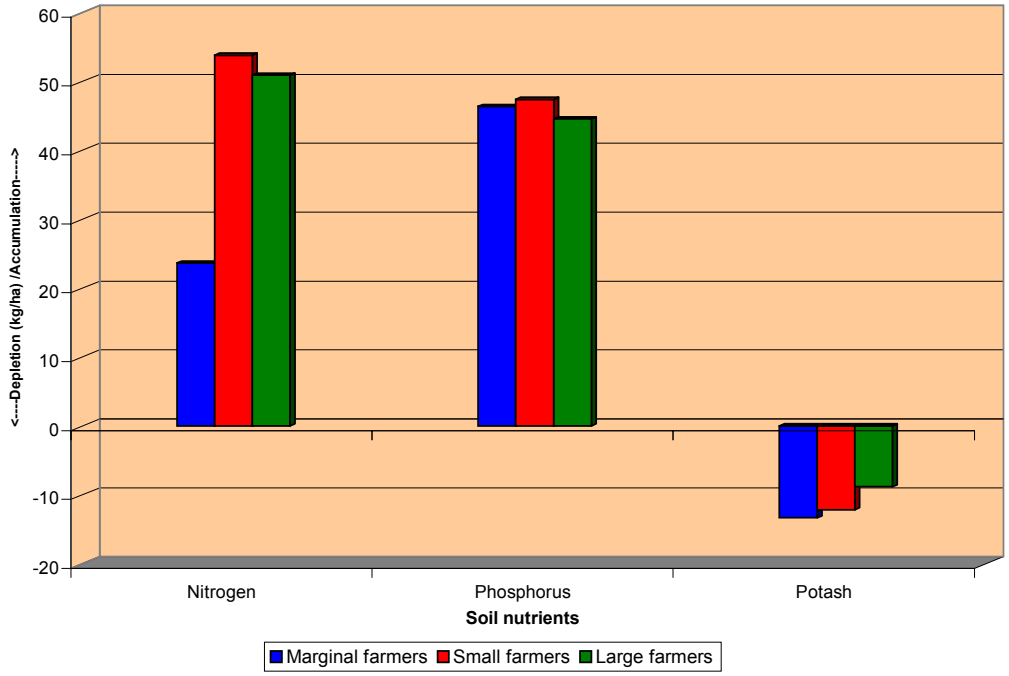


Fig. 4.1 Type II misapplication of nutrients in finger millet cultivation in Garakahalli watershed.

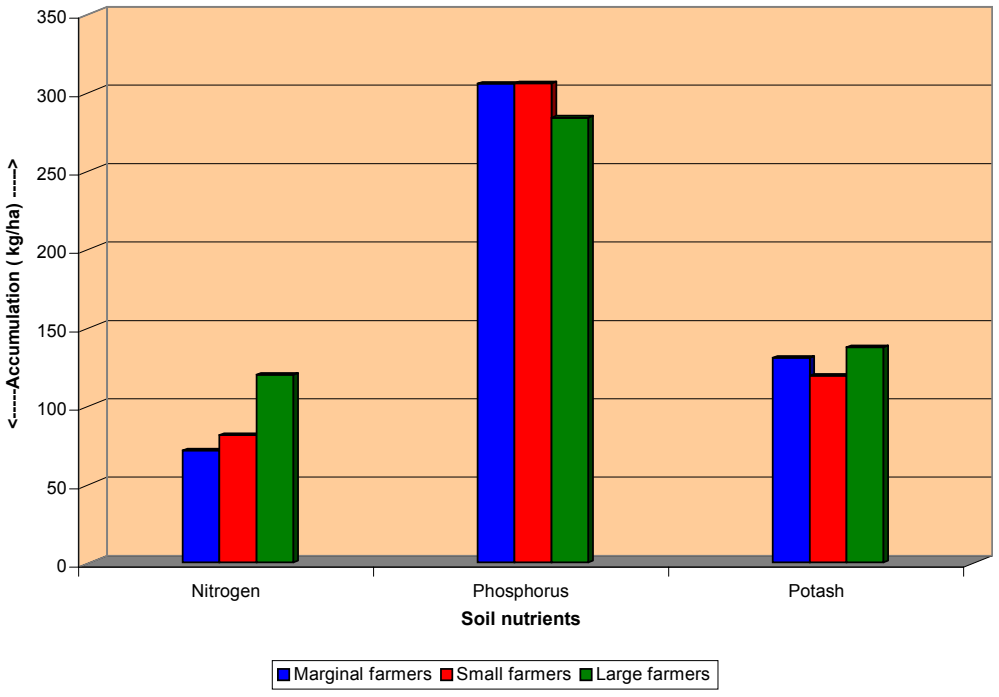


Fig. 4.2 Type II misapplication of nutrients in groundnut cultivation in Garakahalli watershed.

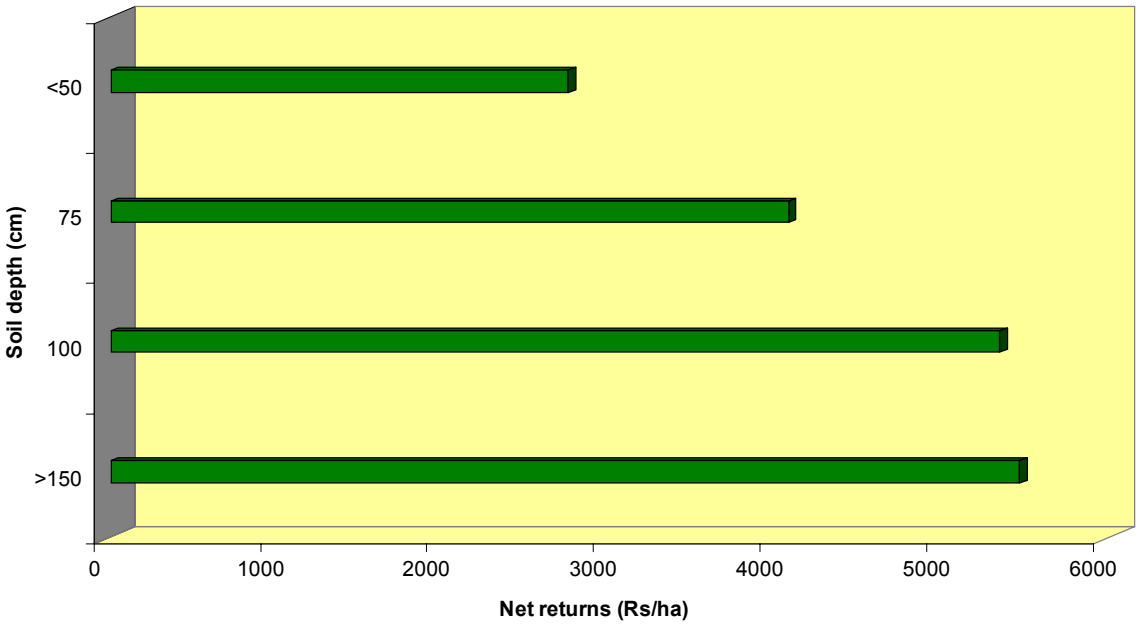


Fig. 4.3 Relationship between net returns from finger millet cultivation and soil depth in Garakahalli watershed.

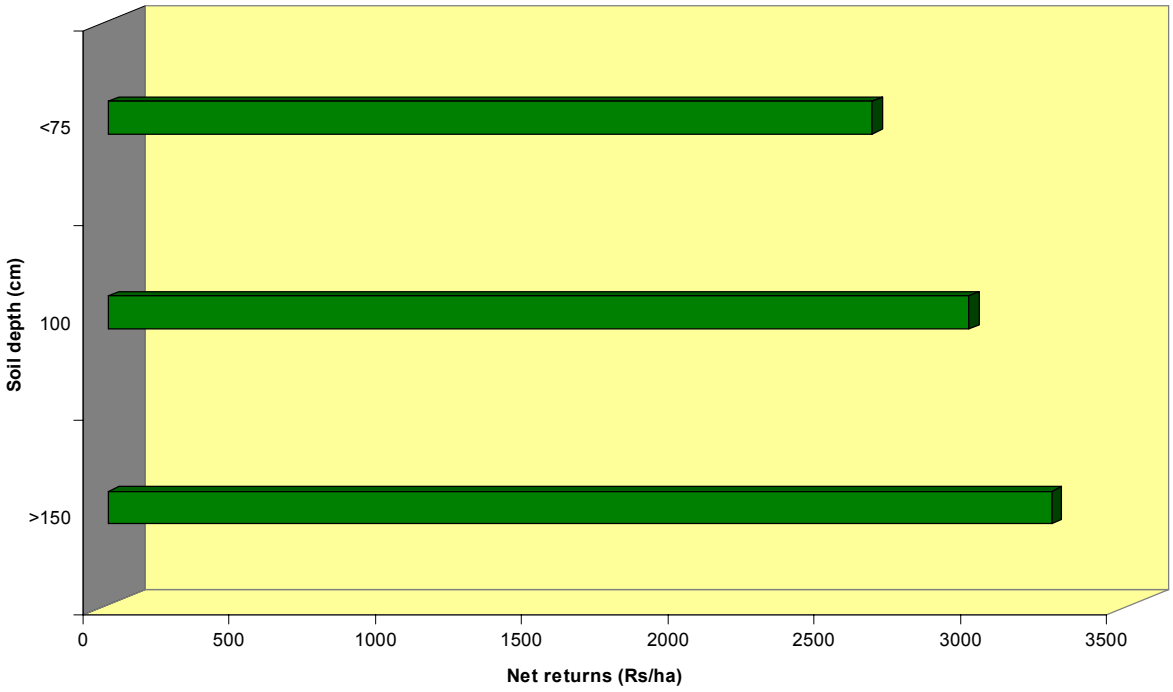


Fig. 4.4 Relationship between net returns from groundnut cultivation and soil depth in Garakahalli watershed

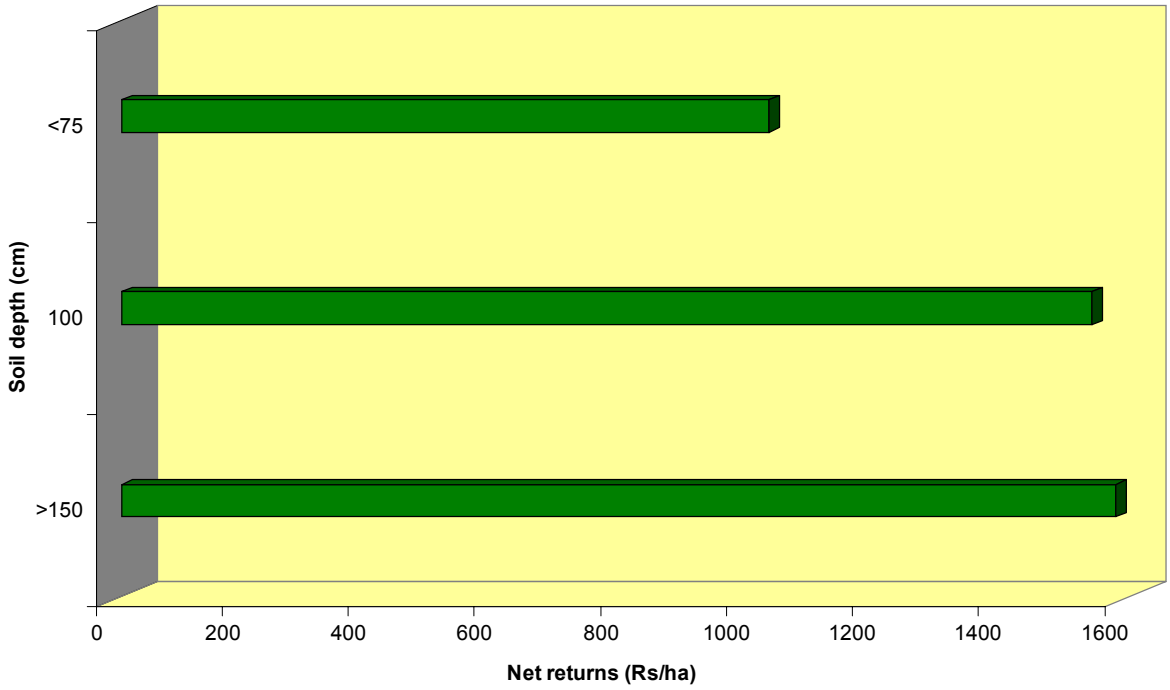


Fig. 4.5 Relationship between net returns from horsegram cultivation and soil depth in Garakahalli watershed.

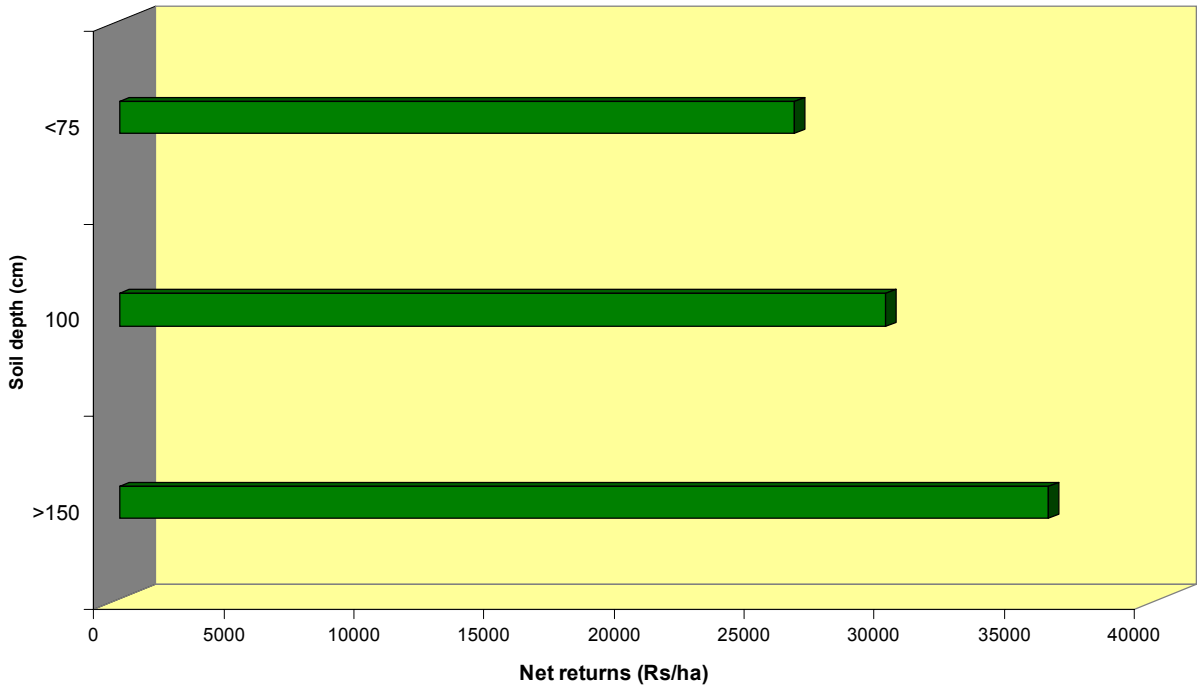


Fig. 4.6 Relationship between net returns from mulberry cultivation and soil depth in Garakahalli watershed.

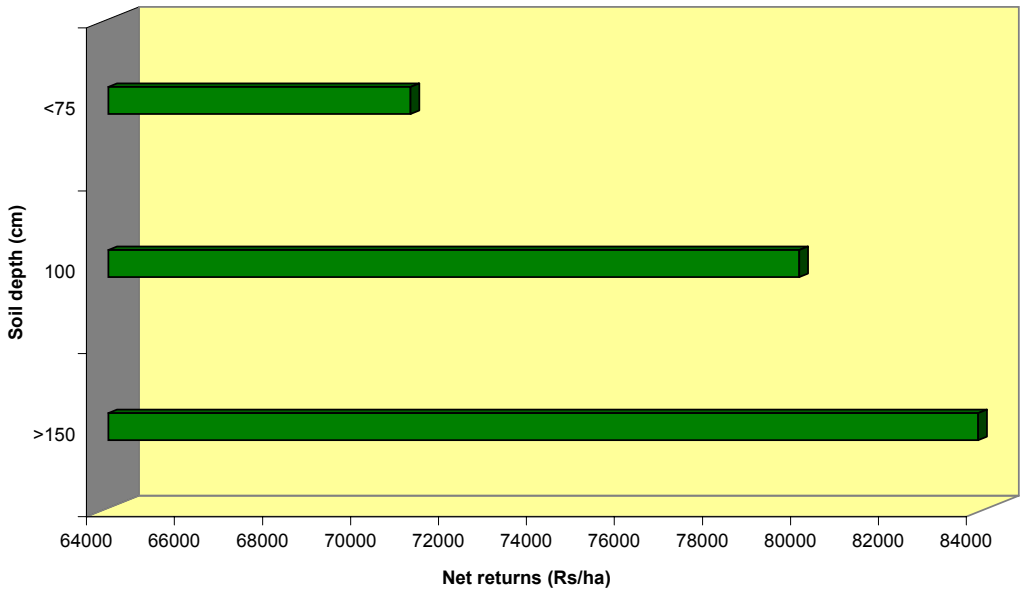


Fig. 4.7 Relationship between net returns from banana cultivation and soil depth in Garakahalli watershed.

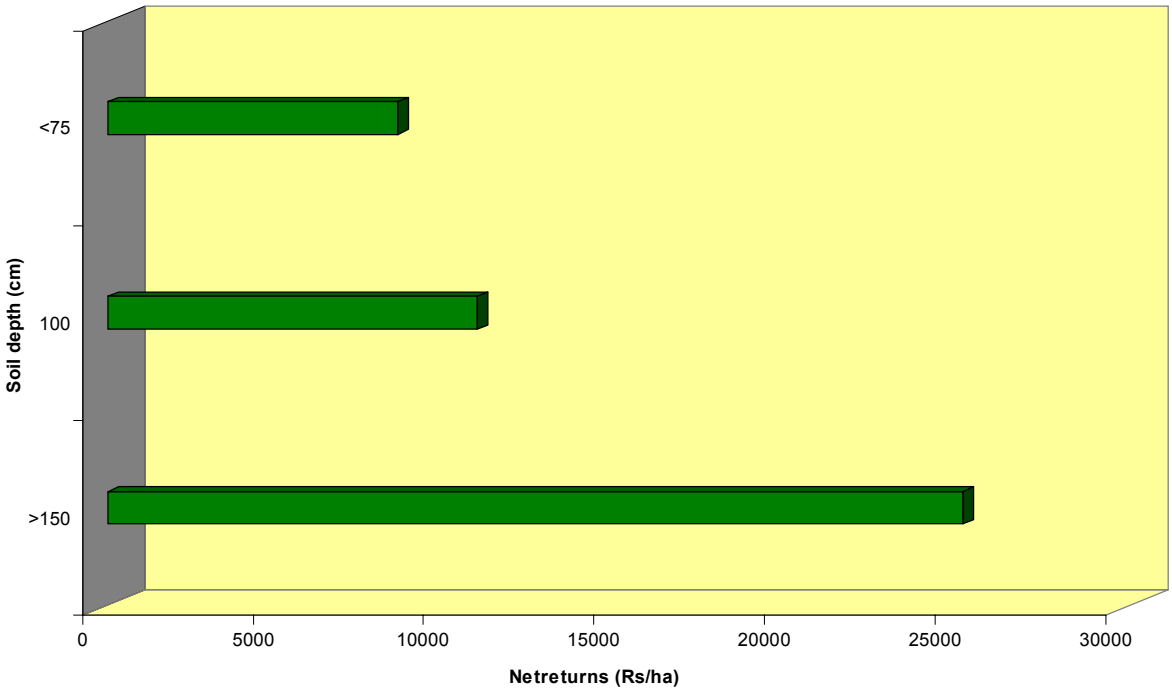


Fig. 4.8 Relationship between net returns from coconut cultivation and soil depth in Garakahalli watershed.

Table 4.2 Marginal productivity and geometric mean levels of the inputs used in finger millet and groundnut cultivation in Garakahalli watershed

Variable	Finger millet			Groundnut		
	Geometric mean level	Marginal productivity	Marginal value of product	Geometric mean level	Marginal productivity	Marginal value of product
Yield (qtl/ha)	12.18			18.65		
Soil depth (cm)	101.66	0.37	18.63	122.50	.097	116.92
Soil erosion (t/ha)	5.17	–0.035	–17.67	5.24	–0.018	–21.35
Soil gravel (%)	15.40	–0.087	–43.50	15.61	0.115	137.63
Farmyard manure (qtl/ha)	15.20	0.096	48.08	8.63	0.136	163.38
Seed (kg/ha)	12.88	0.050	25.06	75.24	0.047	56.52
Nitrogen applied (kg/ha)	59.99	0.006	2.84	21.59	0.046	54.94
Phosphorus applied (kg/ha)	51.99	–0.012	–6.21	52.38	0.041	4.56
Potash applied (kg/ha)	1.81	1.009	504.70	1.05	0.604	724.60
Men labour (man-days)	6.22	0.086	43.08	7.28	0.031	36.89
Women labour (woman-days)	63.10	0.031	15.54	52.00	0.064	76.61
Bullock labour (pair-days)	9.25	–0.093	–46.74	8.11	0.184	220.76
Size of holding (ha)	0.66	–2.159	–1079.59	1.26	–1.081	–1296.62

Table 4.3 Estimation of annual loss of soil nutrients due to soil erosion in Garakahalli watershed

Soil unit	Organic matter. kg		Nitrogen, kg		Phosphorus, kg		Potash, kg		Iron, g		Manganese, g		Copper, g		Zinc, g	
	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total
Ag2hD2St4	312.91	650.22	1.74	3.62	0.31	0.65	0.73	1.53	126	262	351	729	6	12	9	19
BcB1	31.89	118.01	0.41	1.53	0.04	0.16	0.79	2.91	26	97	106	391	3	11	1	5
BmB1	31.89	116.32	0.46	1.66	0.04	0.16	0.31	1.12	45	165	90	328	4	14	3	12
CbB1	16.38	269.30	0.45	7.35	0.09	1.50	0.40	6.65	72	1179	88	1442	3	48	2	33
CcB1	49.13	859.45	1.17	20.51	0.28	4.91	1.33	23.25	169	2960	410	7167	13	224	35	604
CcC2	49.13	155.90	1.36	4.33	0.26	0.81	1.70	5.39	45	142	165	523	12	38	6	20
Cg1bC1	16.38	44.19	0.57	1.53	0.13	0.36	0.75	2.02	32	87	67	180	4	10	3	8
Cg1hB1	16.38	84.41	0.46	2.39	0.06	0.32	0.50	2.57	50	259	129	666	4	19	2	9
Cg2fB1	16.38	21.46	0.67	0.88	0.06	0.08	0.32	0.41	31	41	86	113	4	5	2	3
ChB1	16.38	17.77	0.39	0.43	0.15	0.16	0.93	1.00	93	101	159	172	1	1	2	2
CiC1	16.38	53.31	0.41	1.32	0.10	0.33	0.61	1.97	43	140	76	246	5	15	3	9
Dg1bB1	38.79	59.08	0.36	0.54	0.08	0.12	0.31	0.48	58	88	168	256	5	7	2	3
Dg1bB1St3	38.79	50.12	0.36	0.47	0.04	0.05	0.64	0.82	49	63	156	202	5	6	2	3
Dg1cC1	38.79	84.87	0.39	0.85	0.04	0.09	0.61	1.34	36	79	106	232	2	5	2	5
DmB1	38.79	139.95	0.50	1.79	0.06	0.23	0.36	1.30	56	202	74	265	5	17	3	12
EbB1	26.72	114.61	0.46	1.98	0.14	0.59	0.42	1.80	51	217	96	413	3	14	2	9
Eg1CB1St3	26.72	52.75	0.36	0.70	0.09	0.18	0.24	0.48	51	101	127	251	3	6	2	4
Eg1hB1-R	26.72	142.43	0.47	2.53	0.04	0.20	0.40	2.14	38	201	83	441	4	19	2	10
Eg1iB1	26.72	156.72	0.43	2.52	0.06	0.36	0.50	2.91	24	142	89	520	3	18	2	11
Eg2cC2St4	80.17	163.70	1.00	2.04	0.05	0.10	0.94	1.93	53	108	224	458	6	12	5	10
EmB1	26.72	63.33	0.36	0.86	0.07	0.16	0.61	1.45	62	148	83	196	3	7	2	6
FbB1	24.14	233.93	0.41	3.96	0.05	0.44	0.43	4.13	48	464	67	654	4	35	5	49

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Soil unit	Organic matter. kg		Nitrogen, kg		Phosphorus, kg		Potash, kg		Iron, g		Manganese, g		Copper, g		Zinc, g	
	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total
FcB1	24.14	372.71	0.41	6.32	0.08	1.17	0.61	9.49	49	752	129	1997	4	58	2	36
FhB1	24.14	48.66	0.44	0.88	0.06	0.13	0.43	0.86	100	201	156	314	4	8	2	3
FiB1	24.14	261.83	0.43	4.61	0.05	0.51	0.41	4.50	44	476	84	915	3	38	2	25
GbB1	65.51	87.33	0.43	0.58	0.14	0.18	1.20	1.60	50	67	150	199	3	4	1	2
GbB2	196.54	354.75	1.50	2.71	0.19	0.34	1.36	2.46	117	210	259	468	10	18	6	11
GbC2St3-R	196.54	781.82	1.43	5.70	0.09	0.35	1.25	4.97	101	401	200	795	6	23	6	25
GcB1	65.51	573.82	0.45	3.93	0.06	0.48	0.54	4.69	45	391	133	1167	4	35	2	20
Gg1cE3St4	524.10	771.47	3.51	5.16	0.09	0.14	1.26	1.86	294	433	803	1183	24	36	23	34
Gg1hC1St3	65.51	80.12	0.48	0.59	0.03	0.04	0.25	0.30	24	29	119	145	2	2	2	2
Gg1hE3St4	524.10	915.07	2.36	4.13	0.14	0.24	0.63	1.11	162	282	584	1020	22	39	42	73
Gg1iC1	65.51	58.17	0.49	0.44	0.11	0.09	0.45	0.40	29	25	59	52	2	2	2	2
Gg2cD2St4-R	196.54	399.75	1.52	3.09	0.10	0.20	1.09	2.21	120	245	564	1146	11	21	5	10
Gg2hC2St3	196.54	745.66	1.70	6.46	0.12	0.44	0.71	2.69	86	326	443	1679	9	35	4	15
HbB1	43.10	258.77	0.44	2.64	0.05	0.28	0.31	1.84	33	195	55	329	3	17	2	14
HcB1	43.10	103.83	0.51	1.22	0.08	0.20	0.28	0.67	40	97	52	125	5	13	2	6
HcB1St3	43.10	160.94	0.39	1.45	0.08	0.29	0.52	1.94	78	289	98	366	5	19	4	16
Hg1bB1	43.10	51.50	0.34	0.41	0.09	0.10	0.28	0.33	56	67	131	157	4	5	2	3
Hg1cD2St4	129.30	621.16	1.88	9.03	0.03	0.13	1.12	5.38	73	351	340	1632	10	46	14	68
Hg1hB1	43.10	137.06	0.52	1.65	0.08	0.25	0.62	1.96	65	205	130	414	6	19	2	6
Hg1hD2St4	129.30	312.00	1.73	4.18	0.02	0.04	0.90	2.17	158	381	873	2107	12	28	14	33
Hg1iB1	43.10	128.18	0.35	1.03	0.11	0.32	0.39	1.17	53	157	108	322	4	13	3	10
Hg1iC1	43.10	159.86	0.60	2.21	0.10	0.39	0.36	1.32	67	249	136	503	4	14	2	9
Hg2bB1	43.10	74.43	0.67	1.15	0.12	0.21	0.26	0.45	77	133	153	264	5	8	3	4
Hg2cD2St3	129.30	226.53	1.93	3.39	0.02	0.03	1.00	1.76	75	132	359	629	17	30	10	18

Hg2hD2St4	129.30	531.81	1.60	6.57	0.05	0.21	1.64	6.73	155	637	479	1972	15	63	5	22
Hg2iC1	43.10	99.35	0.63	1.45	0.01	0.02	0.82	1.90	655	1511	75	172	4	8	7	16
HhB1	43.10	263.77	0.42	2.58	0.07	0.42	0.59	3.63	35	212	160	979	4	26	2	14
HmC1St3	43.10	93.01	0.64	1.38	0.02	0.05	0.36	0.77	68	147	323	697	6	13	4	9
IbC1	20.69	54.49	0.52	1.37	0.03	0.07	0.39	1.02	114	300	97	256	3	8	4	10
IcB1	20.69	68.04	0.49	1.60	0.16	0.52	0.51	1.69	42	137	67	221	3	10	5	15
IcC1	20.69	39.41	0.41	0.77	0.05	0.10	0.34	0.64	32	61	72	137	2	5	2	4
Ig1hC1	20.69	24.06	0.43	0.50	0.00	0.01	0.13	0.15	38	44	90	105	3	4	2	2
Ig2hC2St3	62.06	314.48	1.54	7.81	0.07	0.37	2.71	13.72	71	361	135	682	8	41	5	23
IhB1	20.69	101.76	0.47	2.29	0.04	0.18	0.47	2.33	39	192	173	853	5	23	2	9
IiB1	20.69	33.16	0.58	0.93	0.09	0.14	0.52	0.83	61	99	338	542	10	15	2	3
IiC2	62.06	51.26	1.59	1.31	0.02	0.02	0.81	0.67	94	78	356	294	14	11	5	4
ImB1	20.69	133.75	0.41	2.64	0.04	0.23	0.76	4.94	47	307	121	785	4	26	3	18
ImB2	62.06	129.28	1.63	3.40	0.10	0.22	1.13	2.36	69	145	303	632	12	25	5	11
Jg1hD2St3	118.96	209.36	1.32	2.32	0.11	0.19	0.40	0.71	153	269	288	507	6	11	7	12
JhB1	39.65	280.82	0.41	2.89	0.07	0.47	0.71	5.04	48	342	127	901	4	29	36	257
JiB1	39.65	72.09	0.41	0.75	0.02	0.04	0.71	1.29	62	112	130	235	4	7	2	4
KbB1	35.34	680.58	0.56	10.77	0.06	1.12	0.45	8.57	56	1071	122	2343	5	90	3	53
KbC2	106.03	633.40	1.48	8.82	0.18	1.05	0.68	4.06	164	982	274	1638	11	66	6	33
KcB1	35.34	804.70	0.57	12.99	0.06	1.43	0.61	13.96	51	1169	110	2502	5	104	3	74
KcC1	35.34	161.34	0.45	2.04	0.08	0.37	0.36	1.62	40	184	123	561	3	15	3	14
Kg1cB1	35.34	123.17	0.34	1.18	0.23	0.82	0.56	1.96	111	388	197	685	5	17	4	14
Kg1hB1	35.34	89.73	0.36	0.91	0.22	0.56	0.93	2.37	59	151	132	336	5	11	2	6
Kg1hC2St4-R	106.03	477.01	1.18	5.30	0.15	0.67	1.30	5.83	87	390	325	1464	8	36	5	21
Kg2hD2St4-R	106.03	305.04	1.30	3.74	0.26	0.74	2.02	5.81	96	275	338	974	8	24	5	15
KhB1	35.34	1546.95	0.48	20.99	0.06	2.68	0.52	22.81	39	1692	94	4114	4	180	3	129

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Soil unit	Organic matter. kg		Nitrogen, kg		Phosphorus, kg		Potash, kg		Iron, g		Manganese, g		Copper, g		Zinc, g	
	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total	ha^{-1}	Total
KhC1	35.34	110.23	0.33	1.03	0.11	0.33	0.49	1.52	54	168	75	234	3	10	2	6
KhD2	106.03	718.43	1.72	11.64	0.05	0.33	1.41	9.56	89	601	381	2581	9	58	5	34
KhD2St3	106.03	599.36	1.59	9.01	0.05	0.27	0.77	4.33	107	604	525	2966	14	79	5	31
KiC1	35.34	158.69	0.46	2.07	0.05	0.25	0.42	1.88	33	149	89	401	3	13	2	8
KmB1	35.34	586.22	0.52	8.66	0.05	0.80	0.61	10.14	38	638	162	2682	6	101	3	45
Lg1bC2St3	95.68	505.39	1.18	6.25	0.36	1.91	1.28	6.75	145	768	332	1753	9	49	5	27
Lg1cD2St3	95.68	269.54	1.36	3.82	0.33	0.93	0.57	1.62	196	551	363	1022	11	30	6	18
McB1	37.07	36.07	0.39	0.38	0.07	0.07	0.75	0.73	17	17	81	78	3	3	2	2
MhB1	37.07	385.86	0.39	4.05	0.08	0.84	0.60	6.28	46	480	69	718	4	39	2	23
NbB1	37.07	173.62	0.37	1.74	0.06	0.27	0.28	1.31	46	216	92	429	4	20	2	11
NcB1	37.07	400.94	0.41	4.41	0.10	1.10	0.55	5.94	56	605	108	1167	3	35	3	29
NhB1	37.07	144.15	0.46	1.77	0.08	0.32	1.21	4.71	26	102	90	348	4	15	3	11
NiB1	37.07	395.72	0.36	3.87	0.13	1.36	0.83	8.90	60	641	112	1200	5	49	3	29
All units of watershed																
Quantity, kg	52.52	23143.28	0.69	302.77	0.09	39.99	0.69	302.83	68	30133	168	73933	6	2448	5	2354
Value, Rs	26.26	11571.64	7.17	3157.94	1.45	639.92	5.50	2422.63	2244	988954	2476	1091254	82	36132	560	246625
Mean	69.62	272.27	0.79	3.56	0.09	0.47	0.71	3.56	78	355	196	870	6	29	5	28
Min	16.38	17.77	0.33	0.38	0.00	0.01	0.13	0.15	17	17	52	52	1	1	1	2
Max	524.10	1546.95	3.51	20.99	0.36	4.91	2.71	23.25	655	2960	873	7167	24	224	42	604

Table 4.14 Existing cropping pattern and input use in Garakahalli watershed

	Finger millet	Groundnut	Horsegram	Rice	Mulberry	Banana	Coconut	Fallow	Total
Area (ha)	155.56	37.42	22.63	7.45	22.12	17.54	28.44	15.49	306.65
Seeds/ha	19.82	77.63	23.82	76.66	6250.00	1931.00	455.00		
Total seeds	3083.20	2904.91	539.05	571.12	138250.00	33869.74	12940.20		192158.22
FYM/ha	43.29	31.76	10.29	82.21	60.00	146.84	32.00		
Total FYM	6734.19	1188.46	232.86	612.46	1327.20	2575.57	910.08		13580.83
N/ha	71.92	23.40	0.68	98.18	252.34	166.77	25.00		
Total N	11187.88	875.63	15.39	731.44	5581.76	2925.15	711.00		22028.24
P/ha	52.43	58.81	0.00	48.54	111.23	236.02	15.00		
Total P	8156.01	2200.67	0.00	361.62	2460.41	4139.79	426.60		17745.10
K/ha	1.09	0.20	0.00	27.68	103.15	229.64	10.00		
Total K	169.56	7.48	0.00	206.22	2281.68	4027.89	284.40		6977.22
Men labour/ha	6.84	5.34	5.36	43.00	101.00	307.00	98.00		
Total men labour	1064.03	199.82	121.30	320.35	2234.12	5384.78	2787.12		12111.52
Women labour/ha	64.07	53.40	12.13	86.00	97.00	55.87	100.00		
Total women labour	9966.73	1998.23	274.50	640.70	2145.64	979.96	2844.00		18849.76
Bullock-pair labour/ha	8.96	8.28	6.85	9.37	17.75	27.59	10.00		
Total bullock-pair labour	1393.82	309.84	155.02	69.81	392.63	483.93	284.40		3089.44
Cash/ha	7049.98	7543.00	2120.34	11838.10	18374.29	35580.10	11080.75		
Total cash	1096694.20	282259.06	47983.35	88193.83	406439.21	624074.97	315136.53		2860781.15
Net returns/ha	2275.02	3297.38	501.66	5735.90	68225.71	91713.90	11649.25		
Total net returns	353902.80	123387.88	11352.51	42732.47	1509152.79	1608661.79	331304.67		3980494.91

Table 4.15 Normative land-use plans for Garakahalli watershed, area in ha

Crop	Series B	Series C	Series D	Series E	Series F	Series G	Series H	Series I	Series J	Series K	Series L	Series M	Series N	Total
Model I — maximization of net income														
F. millet	7.35	50.61	0.00	21.87	0.00	0.00	51.47	29.95	10.66	19.99	8.10	0.00	0.00	200.00
Groundnut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Horsegram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mulberry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	123.49	0.00	0.00	21.62	145.11
Banana	0.00	0.00	0.00	0.00	38.00	27.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	65.03
Coconut	0.00	0.00	8.61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	11.38	8.45	28.44
Total use	7.35	50.61	8.61	21.87	38.00	27.03	51.47	29.95	10.66	143.48	8.10	11.38	30.07	438.58
Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total area	7.35	50.61	8.61	21.87	38.00	27.03	51.47	29.95	10.66	143.48	8.10	11.38	30.07	438.58
Model II — minimization of cost														
F. millet	7.35	50.61	0.00	0.00	38.00	27.03	38.96	29.95	0.00	0.00	8.10	0.00	0.00	200.00
Groundnut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Horsegram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mulberry	0.00	0.00	8.61	0.00	0.00	0.00	2.13	0.00	0.00	0.00	0.00	11.38	0.00	22.12
Banana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coconut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.44	28.44
Total use	7.35	50.61	8.61	0.00	38.00	27.03	41.09	29.95	0.00	0.00	8.10	11.38	28.44	250.56
Fallow	0.00	0.00	0.00	21.87	0.00	0.00	10.38	0.00	10.66	143.48	0.00	0.00	1.63	188.02
Total area	7.35	50.61	8.61	21.87	38.00	27.03	51.47	29.95	10.66	143.48	8.10	11.38	30.07	438.58
Model III — minimization of bullock labour														
F. millet	0.00	0.00	0.00	0.00	38.00	0.00	0.00	29.95	0.00	123.95	8.10	0.00	0.00	200.00
Groundnut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Horsegram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mulberry	0.00	14.92	7.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.12
Banana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coconut	0.00	0.00	1.41	0.00	0.00	27.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.44
Total use	0.00	14.92	8.61	0.00	38.00	27.03	0.00	29.95	0.00	123.95	8.10	0.00	0.00	250.56
Fallow	7.35	35.69	0.00	21.87	0.00	0.00	51.47	0.00	10.66	19.53	0.00	11.38	30.07	188.02
Total area	7.35	50.61	8.61	21.87	38.00	27.03	51.47	29.95	10.66	143.48	8.10	11.38	30.07	438.58

... contd

Crop	Series B	Series C	Series D	Series E	Series F	Series G	Series H	Series I	Series J	Series K	Series L	Series M	Series N	Total
Model IV — minimization of men labour														
F. millet	7.35	26.53	0.00	0.00	38.00	0.00	37.96	29.95	10.66	0.00	8.10	11.38	30.07	200.00
Groundnut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Horsegram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mulberry	0.00	0.00	8.61	0.00	0.00	0.00	13.51	0.00	0.00	0.00	0.00	0.00	0.00	22.12
Banana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coconut	0.00	1.41	0.00	0.00	0.00	27.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.44
Total use	7.35	27.94	8.61	0.00	38.00	27.03	51.47	29.95	10.66	0.00	8.10	11.38	30.07	250.56
Fallow	0.00	22.67	0.00	21.87	0.00	0.00	0.00	0.00	0.00	143.48	0.00	0.00	0.00	188.02
Total area	7.35	50.61	8.61	21.87	38.00	27.03	51.47	29.95	10.66	143.48	8.10	11.38	30.07	438.58
Model V — minimization of women labour														
F. millet	7.35	50.61	0.00	21.87	0.00	27.03	0.00	0.00	10.66	41.03	0.00	11.38	30.07	200.00
Groundnut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Horsegram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mulberry	0.00	0.00	0.00	0.00	22.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.12
Banana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coconut	0.00	0.00	0.00	0.00	0.00	0.00	28.44	0.00	0.00	0.00	0.00	0.00	0.00	28.44
Total use	7.35	50.61	0.00	21.87	0.00	27.03	28.44	0.00	10.66	41.03	0.00	11.38	30.07	250.56
Fallow	0.00	0.00	8.61	0.00	15.88	0.00	23.03	29.95	0.00	102.45	8.10	0.00	0.00	188.02
Total area	7.35	50.61	8.61	21.87	38.00	27.03	51.47	29.95	10.66	143.48	8.10	11.38	30.07	438.58
Model VI — maximization of FYM														
F. millet	7.35	50.61	8.61	21.87	33.95	0.00	51.47	29.95	10.66	143.48	0.00	0.00	30.07	388.02
Groundnut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Horsegram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mulberry	0.00	0.00	0.00	0.00	0.00	2.64	0.00	0.00	0.00	0.00	8.10.	11.38	0.00	22.12
Banana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coconut	0.00	0.00	0.00	0.00	4.05	24.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28.44
Total use	7.35	50.61	8.61	21.87	38.00	27.03	51.47	29.95	10.66	143.48	8.10	11.38	30.07	438.58
Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total area	7.35	50.61	8.61	21.87	38.00	27.03	51.47	29.95	10.66	143.48	8.10	11.38	30.07	438.58

Model VII — minimization of nitrogen use														
F. millet	7.35	50.61	8.61	21.87	15.88	27.03	51.47	17.18	0.00	0.00	0.00	0.00	0.00	200.00
Groundnut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Horsegram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mulberry	0.00	0.00	0.00	0.00	22.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.12
Banana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coconut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.66	6.40	0.00	11.38	0.00	28.44
Total use	7.35	50.61	8.61	21.87	38.00	27.03	51.47	17.18	10.66	6.40	8.10	11.38	0.00	250.56
Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.77	0.00	137.08	0.00	0.00	30.07	188.02
Total area	7.35	50.61	8.61	21.87	38.00	27.03	51.47	29.95	10.66	143.48	8.10	11.38	30.07	438.58
Model VIII — minimization of phosphorus use														
F. millet	7.35	50.61	8.61	21.87	38.00	27.03	40.73	0.00	0.00	0.00	5.80	0.00	0.00	200.00
Groundnut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Horsegram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	125.70	0.00	0.00	0.00	125.70
Mulberry	0.00	0.00	0.00	0.00	0.00	0.00	10.74	0.00	0.00	0.00	0.00	11.38	0.00	22.12
Banana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coconut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10.66	17.78	0.00	0.00	0.00	28.44
Total use	7.35	50.61	8.61	21.87	38.00	27.03	51.47	0.00	10.66	143.48	5.80	11.38	0.00	376.26
Fallow	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.95	0.00	0.00	2.30	0.00	30.07	62.32
Total area	7.35	50.61	8.61	21.87	38.00	27.03	51.47	29.95	10.66	143.48	8.10	11.38	30.07	438.58
Model IX — minimization of potash use														
F. millet	7.35	50.61	8.61	0.00	37.75	27.03	0.00	29.95	10.66	0.00	8.10	11.38	8.56	200.00
Groundnut	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	143.48	0.00	0.00	0.00	143.48
Horsegram	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Mulberry	0.00	0.00	0.00	21.87	0.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	22.12
Banana	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Coconut	0.00	0.00	0.00	0.00	0.00	0.00	28.44	0.00	0.00	0.00	0.00	0.00	0.00	28.44
Total use	7.35	50.61	8.61	21.87	38.00	27.03	28.44	29.95	10.66	143.48	8.10	11.38	8.56	394.04
Fallow	0.00	0.00	0.00	0.00	0.00	0.00	23.03	0.00	0.00	0.00	0.00	0.00	21.51	44.54
Total area	7.35	50.61	8.61	21.87	38.00	27.03	51.47	29.95	10.66	143.48	8.10	11.38	30.07	438.58

Table 4.16 Input use and net income in different models — Garakahalli watershed

Item	Maximization of net income	Minimization of cash expenses	Minimization of bullock labour	Minimization of men labour	Minimization of women labour	Maximization of FYM	Minimization of nitrogen	Minimization of phosphorus	Minimization of potash
Net returns (Rs)	9491343.53	1907833.27	1803622.96	1572060.49	1724317.57	2106058.91	1881937.76	1949285.90	2114128.61
Total cost (Rs)	4086667.65	1316168.99	1386386.74	1332427.74	1477429.45	2421505.68	1392418.60	1674124.13	2372415.28
Total bullock labour (bullock-pair days)	7710.79	4336.94	3626.52	3908.34	4521.58	7223.81	4319.93	4977.49	6661.97
Total men labour (md)	28689.17	5146.28	5336.23	4652.63	8116.74	9004.07	7371.71	7717.37	9296.20
Total women labour (wd)	30296.62	13063.67	14253.94	13767.74	11083.88	25377.53	11763.95	21259.39	22875.32
Total FYM (t)	5455.09	3299.91	3287.14	3302.65	3612.75	6878.54	3790.96	3881.88	4145.19
Total nitrogen (kg)	23608.49	9088.68	10922.08	10049.86	9725.82	19266.17	8063.04	8239.19	13618.96
Total phosphorus (kg)	16489.53	5654.61	7979.30	6524.21	7471.41	12951.46	5801.02	5109.88	19048.28
Total potash (kg)	13541.34	707.04	1138.32	570.28	112.39	1007.25	195.56	594.95	9.07

Table 4.17 Pay off matrix for the nine objectives and the ideal points — Garakahalli watershed

	Objectives optimized									
Corresponding value of the objectives	MAXNI	MINCAH	MINBP	MINML	MINWL	MAXFYM	MIN_N	MIN_P	MIN_K	Ideal point
Net income	9491343.53	1907833.27	1803622.96	1572060.49	1724317.57	2106058.91	1881937.76	1949285.90	2114128.61	9491343.53
Costs	4086667.65	1316168.99	1386386.74	1332427.74	1477429.45	2421505.68	1392418.60	1674124.13	2372415.28	1316168.99
Bullock labour	7710.79	4336.94	3626.52	3908.34	4521.58	7223.81	4319.93	4977.49	6661.97	3626.52
Men labour	28689.17	5146.28	5336.23	4652.63	8116.74	9004.07	7371.71	7717.37	9296.20	4652.63
Women labour	30296.62	13063.67	14253.94	13767.74	11083.88	25377.53	11763.95	21259.39	22875.32	11083.88
Farmyard manure	5455.09	3299.91	3287.14	3302.65	3612.75	6878.54	3790.96	3881.88	4145.19	6878.54
Nitrogen	23608.49	9088.68	10922.08	10049.86	9725.82	19266.17	8063.04	8239.19	13618.96	8063.04
Phosphorus	16489.53	5654.61	7979.30	6524.21	7471.41	12951.46	5801.02	5109.88	19048.28	5109.88
Potassium	13541.34	707.04	1138.32	570.28	112.39	1007.25	195.56	594.95	9.07	9.07

5. CHARACTERIZATION OF FARM-LEVEL SUSTAINABILITY INDICATORS

FOR FINGER MILLET CULTIVATION

Ten sustainable land management indicators for the three groups of farmers in Garaka-halli watershed are presented in Table 5.1.

5.1 Nutrient Management Index

Nutrient management was operationalized as addition of organic and inorganic fertilizers and amendments to soil at proper time, method and combination aimed at deriving maximum benefits and causing minimum damage to the resource base. Marginal farmers obtained highest mean nutrient management index (29.13) among all categories of farmers followed by pooled data (28.48), small farmers (27.98) and large farmers (24.76). The 211 farmers' plots were divided into five classes based on their nutrient management index values, namely, extremely low (<20.0), very low (20.0–25.0), low (25.0–30.0), moderate (30.0–35.0) and reasonable (>35.0). The largest number of plots (71) was in moderate class, followed by 52 in low, 51 in very low, 24 in extremely low and 13 plots in reasonable class (Fig. 5.1).

Marginal farmers applied 53 qtl/ha farmyard manure, the highest among all farmers. The recommended N:P:K dosage for rainfed finger millet is 50:40:25. Marginal farmers applied 58:55:1, small farmers 81:54:0.5 and large farmers 77:49:2. Thus K was being applied in negli-gible quantities. No farmer was applying biofertilizers and crop residues.

5.2 Land Productivity Index

Land productivity was operationalized as yield per unit area, expressed in qtl/ha. Margi-nal farmers achieved highest yield of 14.56 qtl/ha followed by pooled data (13.98), small farmers (13.16) and large farmers (12.27), that is, there was not much difference among farmer categories. This is a good yield when compared with the potential yield (17.5 qtl/ha). The 211 plots were divided into five classes based on their land productivity. The largest number of plots was in 13.0–15.0 qtl/ha class, 61

in 11.0–13.0 qtl/ha class, 43 in 15.0–17.0 qtl/ha class, 20 plots in <11 qtl/ha class and 11 plots recorded yield >17.0 qtl/ha (Fig. 5.2).

5.3 Input Productivity Index

Input productivity is considered as output per unit input used. In this study, it was exp-ressed as the ratio of gross output to the total variable cost. All the farmer categories were in the narrow input productivity range of 1.34 to 1.38. The 211 plots were divided into five classes based on their input productivity index values. The largest number of plots (86) was in 1.25–1.5 class, followed by 69 in <1.25 class, 25 in 1.5–1.75 class, 24 in 1.75–2.0 class and seven plots in >2.0 class (Fig. 5.3).

Although the crop yield was satisfactory, the medium-to-high cost of cultivation and low market price (Rs. 480–500/qtl) diminished the net returns, which fell in the range Rs 870–1200.

5.4 Crop Yield Security Index

Crop yield security was operationalized as the extent to which farmers managed the crops so as to withstand external crisis due to excess or shortage of rainfall, outbreak of pests and diseases, non-availability of inputs and inability of the farmers to take up timely operations. Marginal farmers obtained highest mean crop yield security index of 72.82 followed by pooled data (69.9), small farmers (65.78) and large farmers (61.34). The 211 plots were divided into five classes based on their crop yield security value, namely, very low (<55.0), low (55.0–65.0), moderate (65.0–75.0), reasonable (75.0–85.0) and satisfactory (>85.0). The largest number of plots (76) was in mode-rate class, followed by 61 in low, 43 in reasonable, 20 in very low and 11 in satisfactory class (Fig. 5.4).

About 90 per cent of finger millet cultivation was under uncertain and abnormal weather conditions. Irregular rains and inadequate alternative sources of irrigation at maturity greatly affected the final yield. The crop was grown under low-management situations and the full package of practices was not followed since the major

proportion of farmers consisted of small and marginal farmers. Poor plant population, inadequate plant protection, improper fertilizer application and poor adoption of post-harvest technology contributed to medium productivity.

5.5 Input Self Sufficiency Index

Input self-sufficiency was operationalized as the extent to which the farmers were able to meet the input requirements of the farming from their own resources rather than purchased. It was calculated as the ratio of the value of owned inputs to the total value of the inputs used in the farming. Marginal farmers obtained highest mean input self sufficiency of 65.33 (Table 5.1) followed by pooled data (61.94), small farmers (56.97) and large farmers (52.8). The 211 plots were divided into five classes based on their input self-sufficiency value, namely, very low (<40.0), low (40.0–50.0), moderate (50.0–60.0), reasonable (60.0–70.0) and satisfactory (>70.0). There were 91 plots in reasonable class, followed by 65 plots in moderate, 21 plots in low, 18 plots in very low and 16 plots in satisfactory class (Fig. 5.5).

5.6 Family Food Sufficiency Index

This index was operationalized as the extent to which the farm families possessed sufficient food grains required for family consumption. It was measured in terms of the ratio (expressed in per cent) of the quantity of food grain available for consumption to that required for the entire year. Large farmers achieved highest mean family food sufficiency of 61.05 followed by small farmers (54.83), pooled data (54.36) and marginal farmers (53.40). The 211 plots were divided into five classes based on their family food sufficiency index, namely, extremely deficit (<50.0), highly deficit (50.0–55.0), moderately deficit (55.0–60.0), moderately sufficient (60.0–65.0) and sufficient (>65.0). Eighty plots fell in highly deficit class, 64 in moderately deficit class, 33 in extremely deficit class, 23 in moderately sufficient class and 11 in sufficient class (Fig. 5.6).

5.7 Ecological Safety Index

Marginal farmers had highest mean ecological safety index (47.86) followed by pooled data (47.17), small farmers (46.63) and large farmers (42.86). The 211 plots were divided into five classes based on their ecological safety index values, namely, extremely unsafe (<30.0), highly unsafe (30.0–40.0), moderately unsafe (40.0–50.0), moderately safe (50.0–60.0) and reasonably safe (>60.0). The largest number (71) was in moderately safe class, followed by 65 in moderately unsafe class, 40 in highly unsafe class, 23 in extremely unsafe class and 12 in reasonably safe class (Fig.5.7).

5.8 Economic Security Index

Highest mean economic security index was observed among marginal farmers owing to their higher land productivity and crop yield security. They were followed by pooled data (55.72), small farmers (52.31) and large farmers (48.17). The 211 plots were divided into five classes based on economic security index values, namely, highly insecure (<50.0), moderately insecure (50.0–55.0), moderately secure (55.0–60.0), reasonably secure (60.0–65.0) and secure (>65.0). There were 80 plots in moderately insecure class, followed by 64 plots in moderately secure class, 33 plots in highly insecure class, 23 plots in reasonably secure class and 11 plots in secure class (Fig. 5.8).

5.9 Social Stability Index

Large farmers obtained highest mean social stability index (66.87) followed by marginal farmers (63.59), pooled data (60.39) and small farmers (52.22). The 211 plots were divided into five classes based on their social stability index values, namely, highly unstable (<50.0), mode-rately unstable (50.0–55.0), moderately stable (55.0–60.0), reasonably stable (60.0–65.0) and stable (>65.0). There were 58 plots in reasonably stable class, 52 in stable class, 39 in highly unstable class and 31 each in moderately unstable and moderately stable classes (Fig. 5.9).

5.10 Sustainability Index

The mean sustainability index was highest (56.81) for marginal farmers, but their indices ranged from a low of 25.39 to a high of 75.82, a range of 50.44. Small and large farmers had nearly the same mean values, but the ranges of values were 33.60–78.25 for small farmers and 40.07–61.38 for large farmers. The 211 plots were divided into five classes based on sustain-ability index values, namely, extremely unsustainable (<45.0), highly unsustainable (45.0–50.0), moderately unsustainable (50.0–55.0), moderately sustainable (55.0–60.0) and reasonably sustainable (>60.0). There were 93 plots in moderately unsustainable class, followed by 45 each in highly unsustainable and moderately sustainable classes, 15 in extremely unsustainable class and 13 plots in reasonably sustainable class (Fig. 5.10).

All farmers who grew finger millet had sustainability index in the range 50.0–57.0. Slightly higher index value among marginal farmers was the resultant of their higher nutrient management, land productivity, crop yield security and input self-sufficiency.

Table 5.1 Sustainable land management indicators for finger millet cultivation in Garakahalli watershed

Indicator	Marginal farmers			Small farmers			Large farmers			Pooled data		
	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Nutrient management index	13.33	60.00	29.13	0.00	60.00	27.98	13.33	46.67	24.76	0.00	60.00	28.48
Land productivity index	5.68	18.33	14.56	2.86	20.00	13.16	9.38	15.00	12.27	2.86	20.00	13.98
Input productivity index	0.62	3.38	1.34	0.53	3.49	1.38	0.98	1.86	1.35	0.53	3.49	1.36
Crop yield security index	28.41	91.67	72.82	14.29	100.00	65.78	46.88	75.00	61.34	14.29	100.00	69.90
Input self-sufficiency index	6.30	90.45	65.33	34.90	78.57	56.97	20.62	67.36	52.80	6.30	90.45	61.94
Family food-sufficiency index	15.56	75.00	53.40	29.61	87.04	54.83	48.81	84.06	61.05	15.56	87.04	54.36
Ecological safety index	0.00	100.00	47.86	0.00	100.00	46.63	22.22	100.00	42.86	0.00	100.00	47.14
Economic security index	13.58	80.73	58.19	0.00	82.06	52.31	32.34	61.83	48.17	0.00	82.06	55.72
Social stability index	10.90	86.26	63.59	19.33	82.82	52.22	17.72	93.97	66.87	10.90	93.97	60.39
Sustainability index	25.38	75.82	56.81	33.60	78.25	50.69	40.07	61.38	50.92	25.38	78.25	54.55

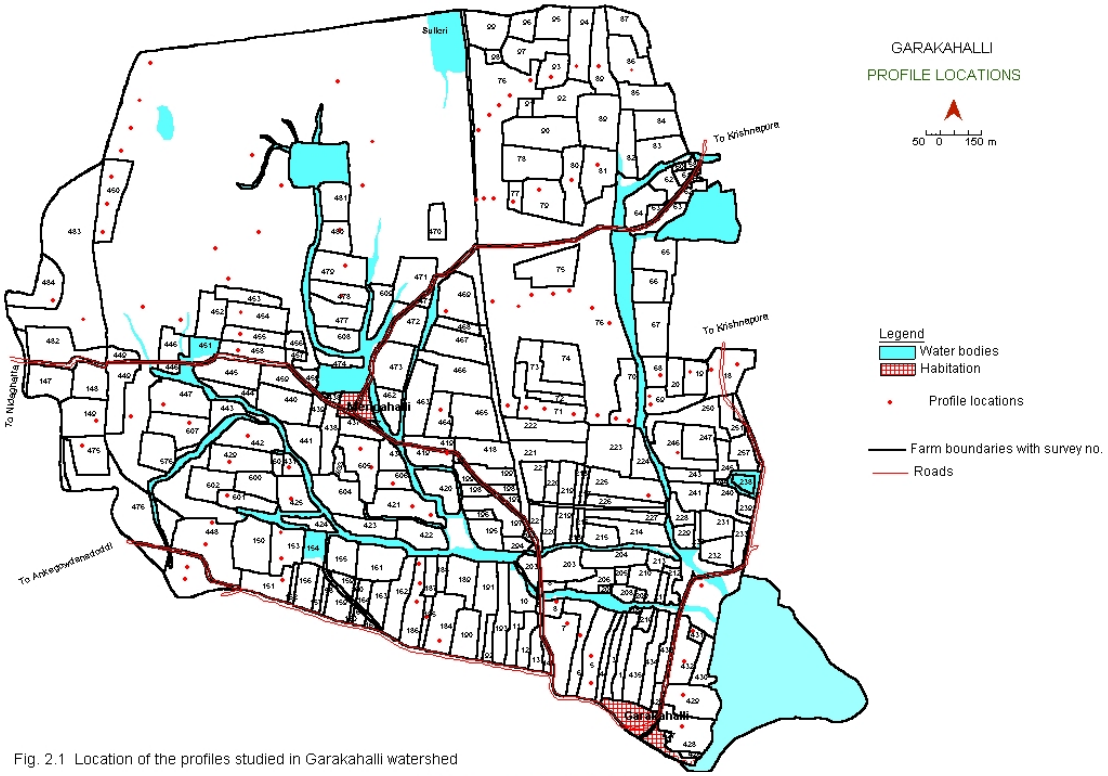

Fig. 2.1 Location of the profiles studied in Garakahalli watershed

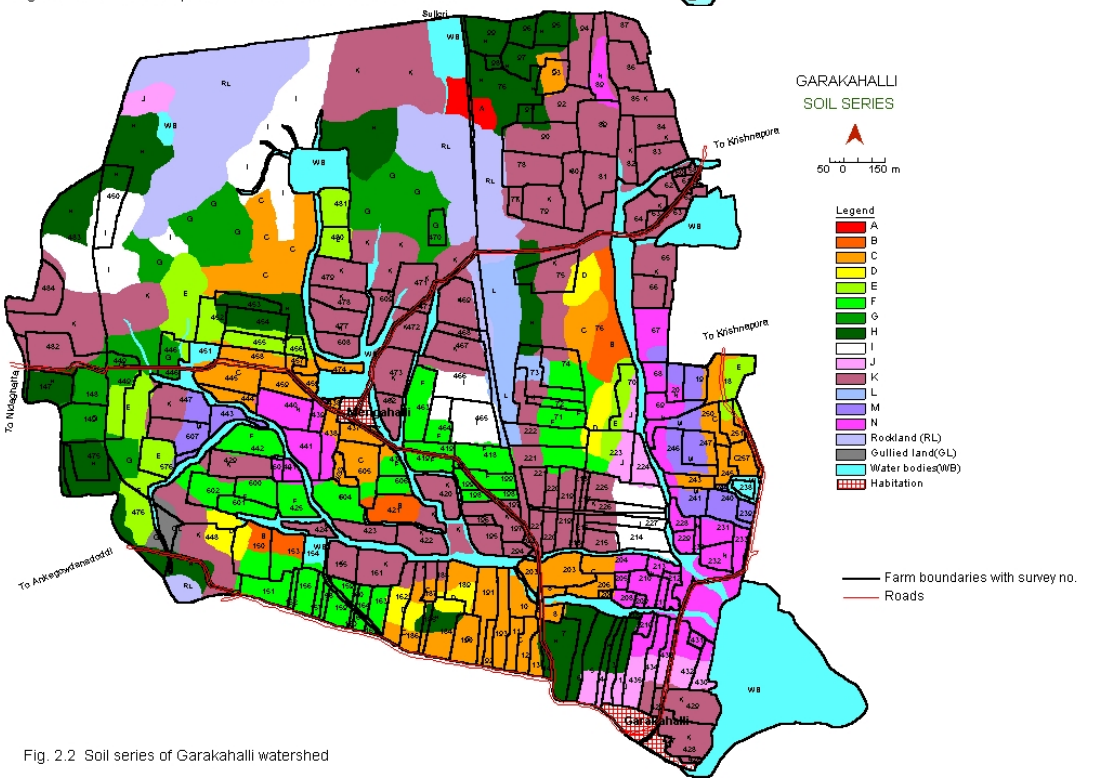

Fig. 2.2 Soil series of Garakahalli watershed

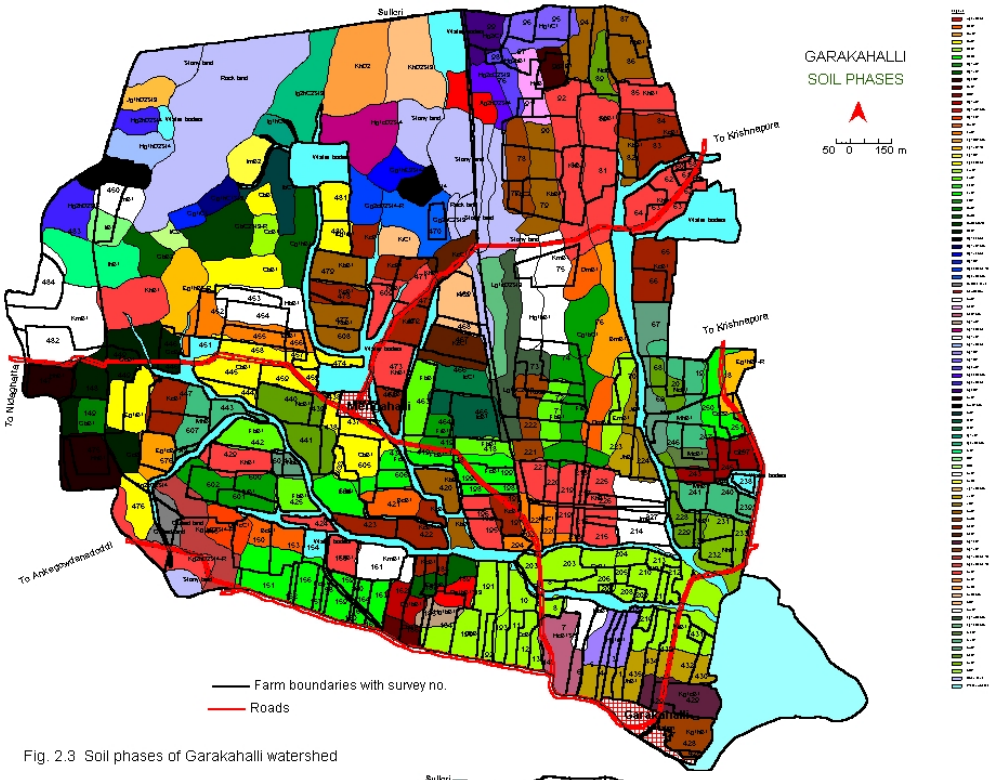

Fig. 2.3 Soil phases of Garakahalli watershed

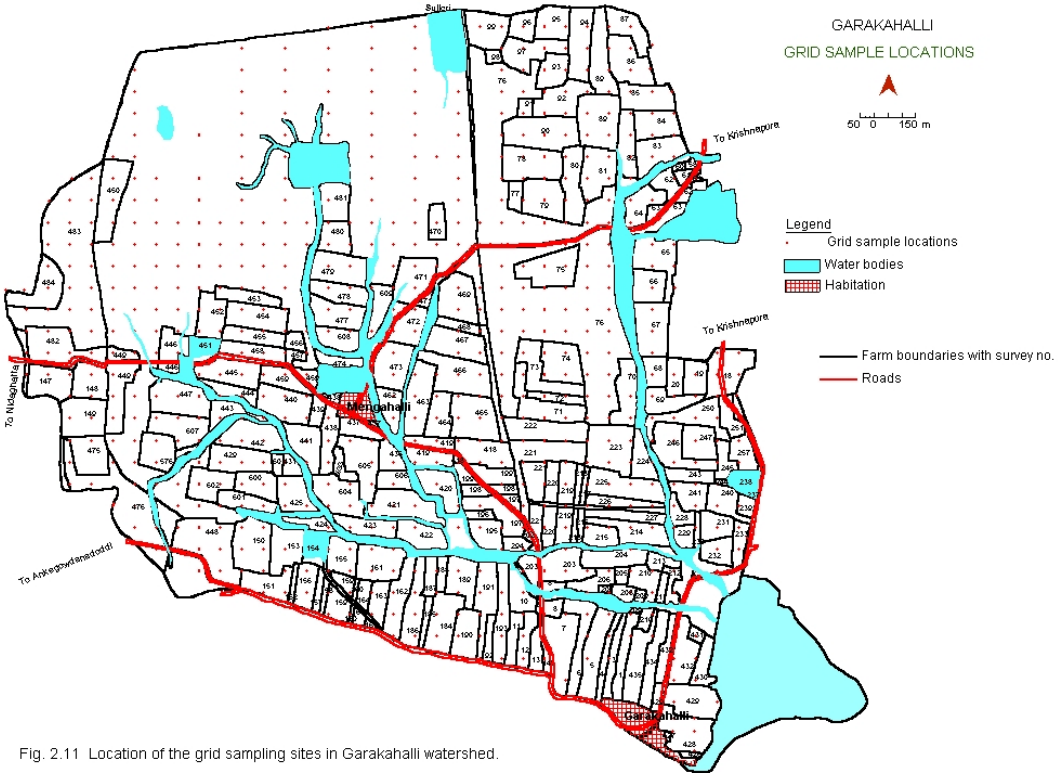

Fig. 2.11 Location of the grid sampling sites in Garakahalli watershed.

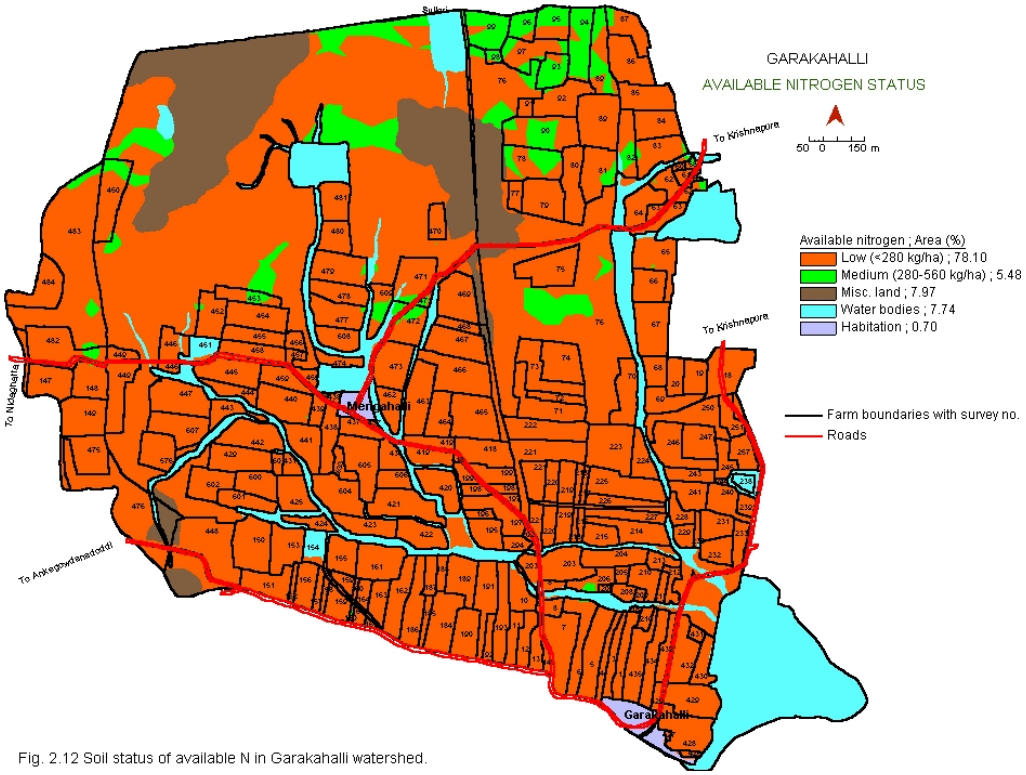

Fig. 2.12 Soil status of available N in Garakahalli watershed.

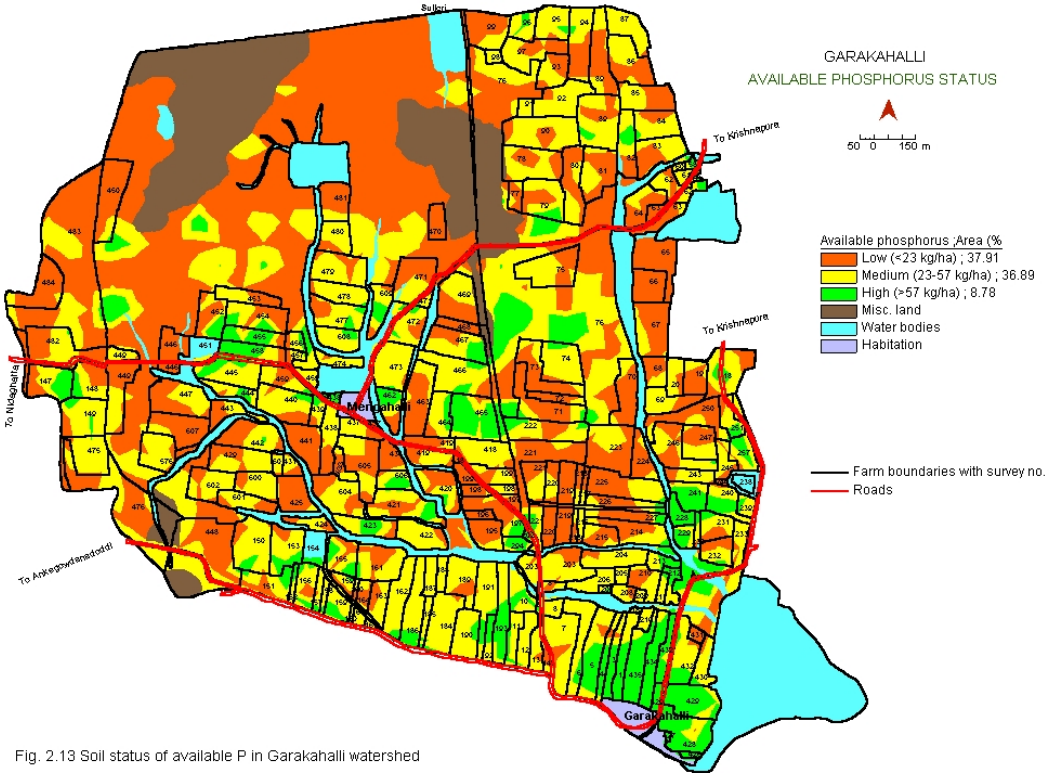

Fig. 2.13 Soil status of available P in Garakahalli watershed

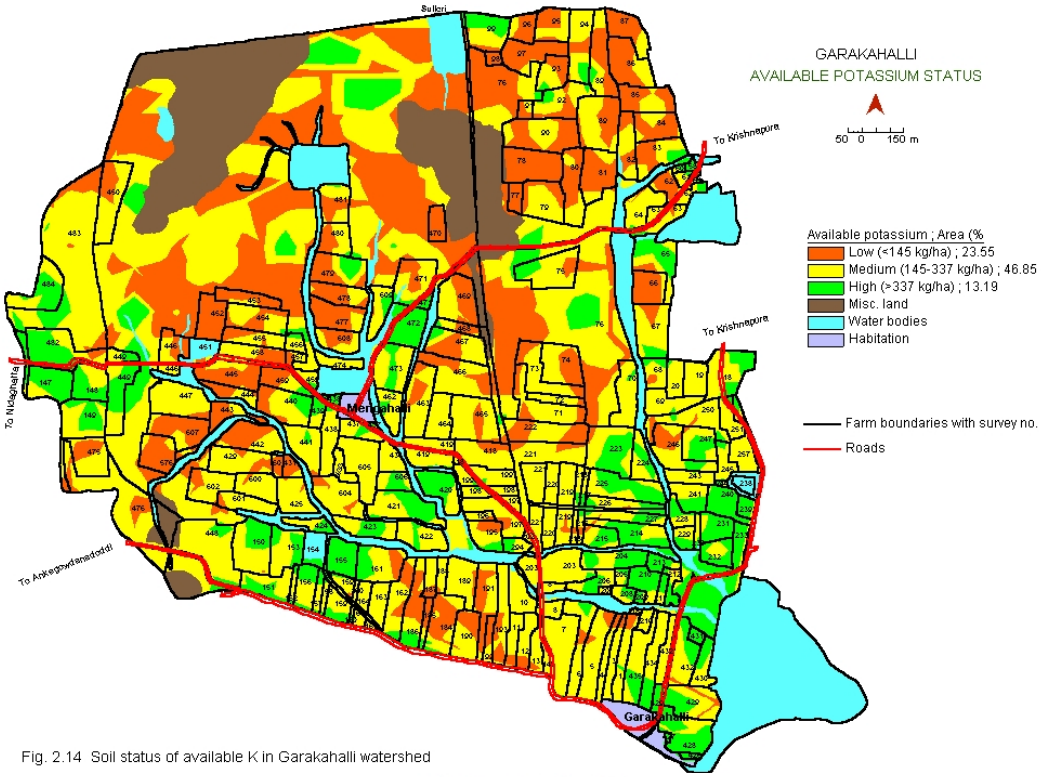

Fig. 2.14 Soil status of available K in Garakahalli watershed

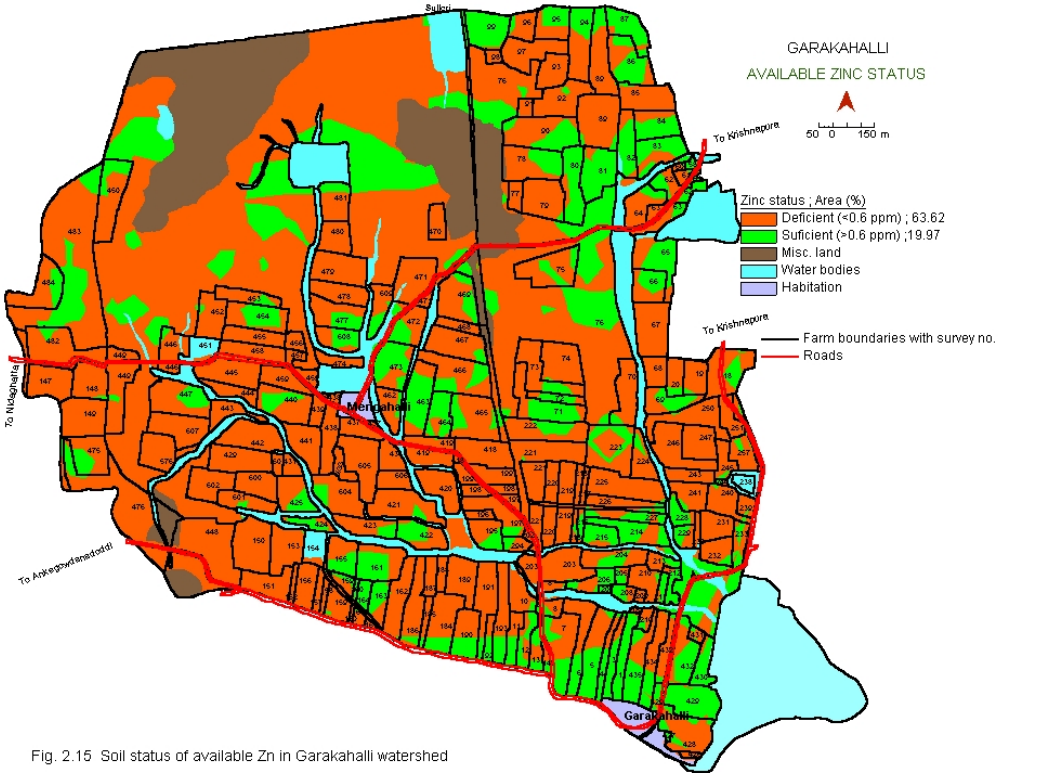

Fig. 2.15 Soil status of available Zn in Garakahalli watershed

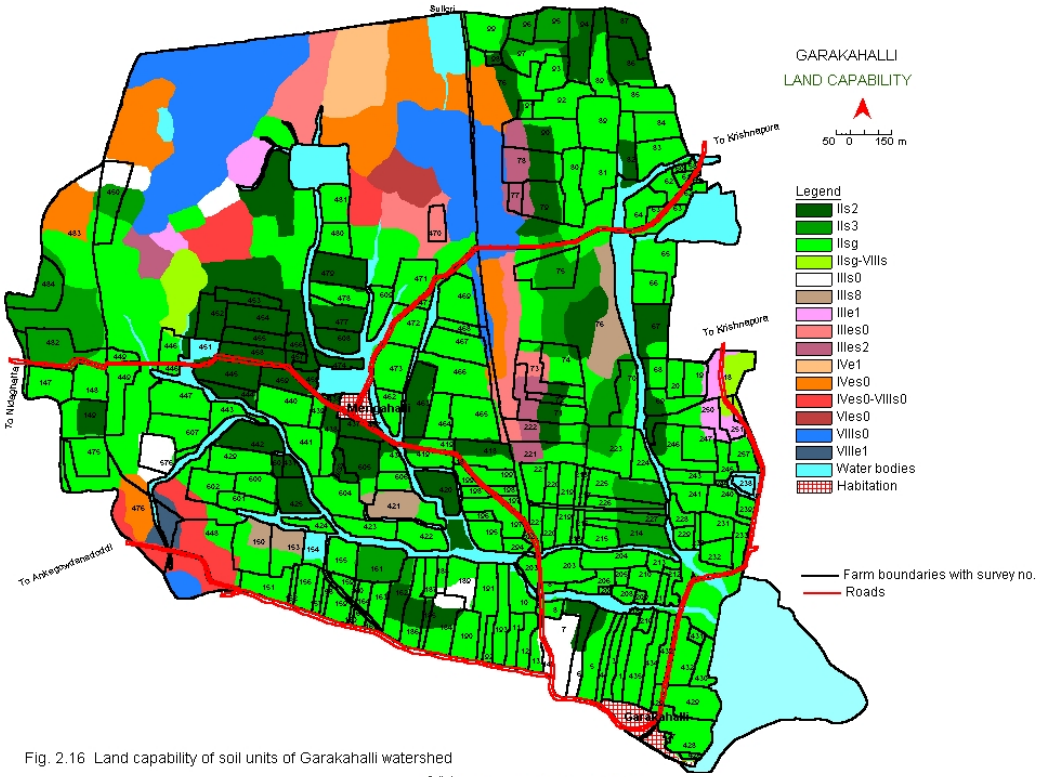

Fig. 2.16 Land capability of soil units of Garakahalli watershed

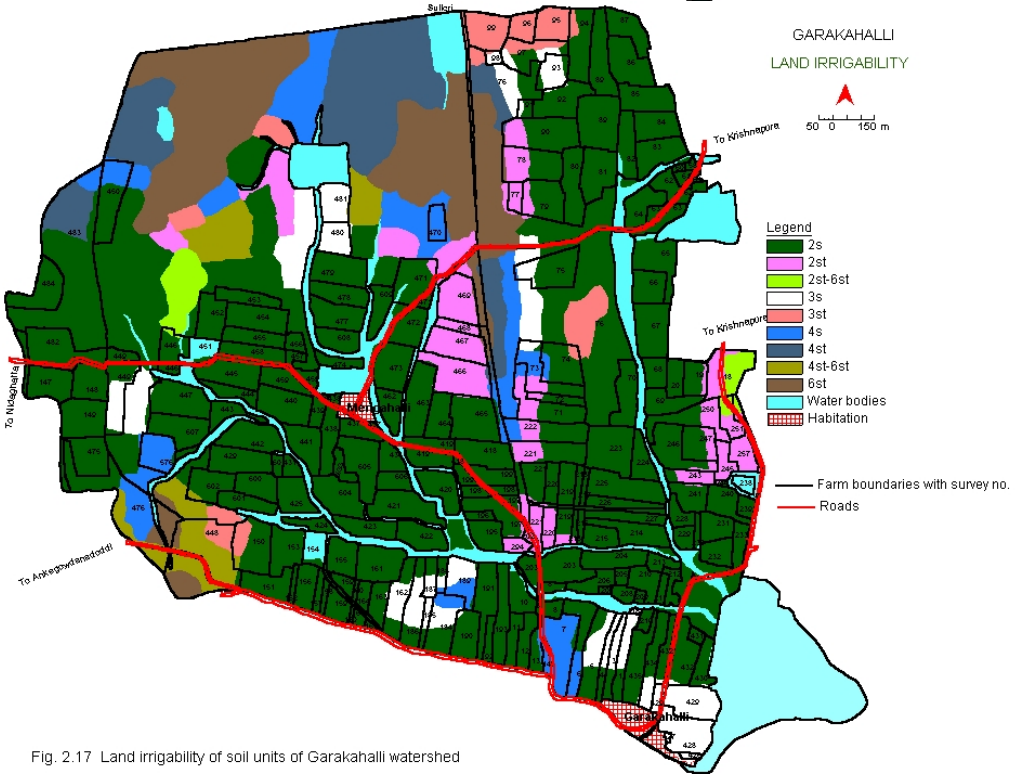

Fig. 2.17 Land irrigability of soil units of Garakahalli watershed

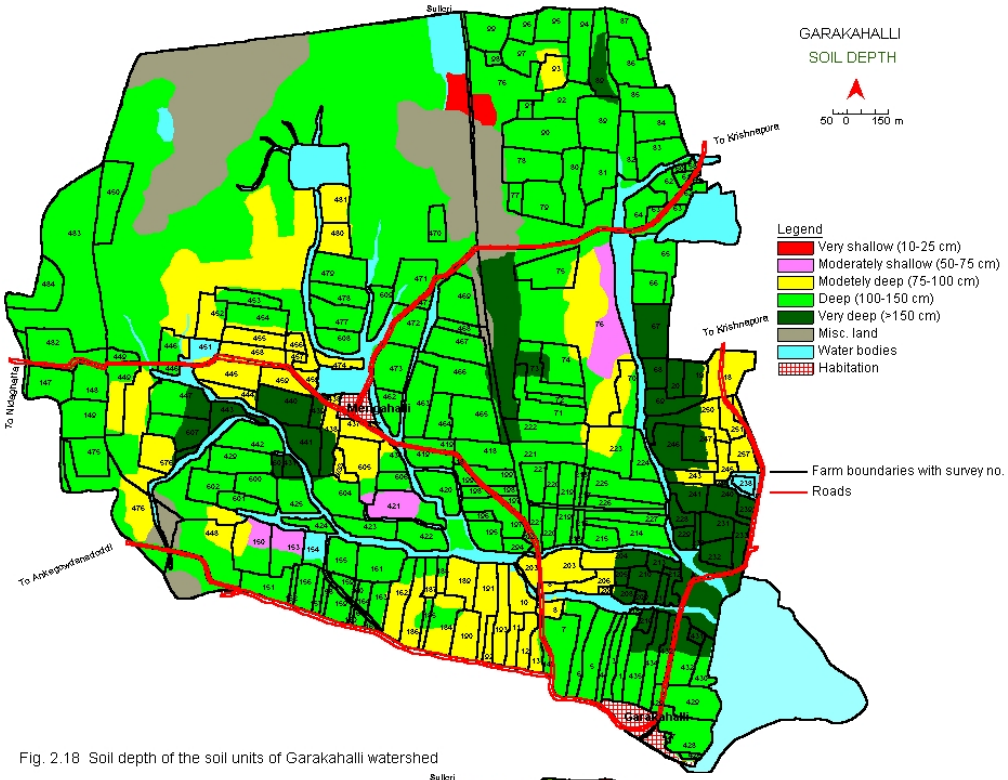

Fig. 2.18 Soil depth of the soil units of Garakahalli watershed

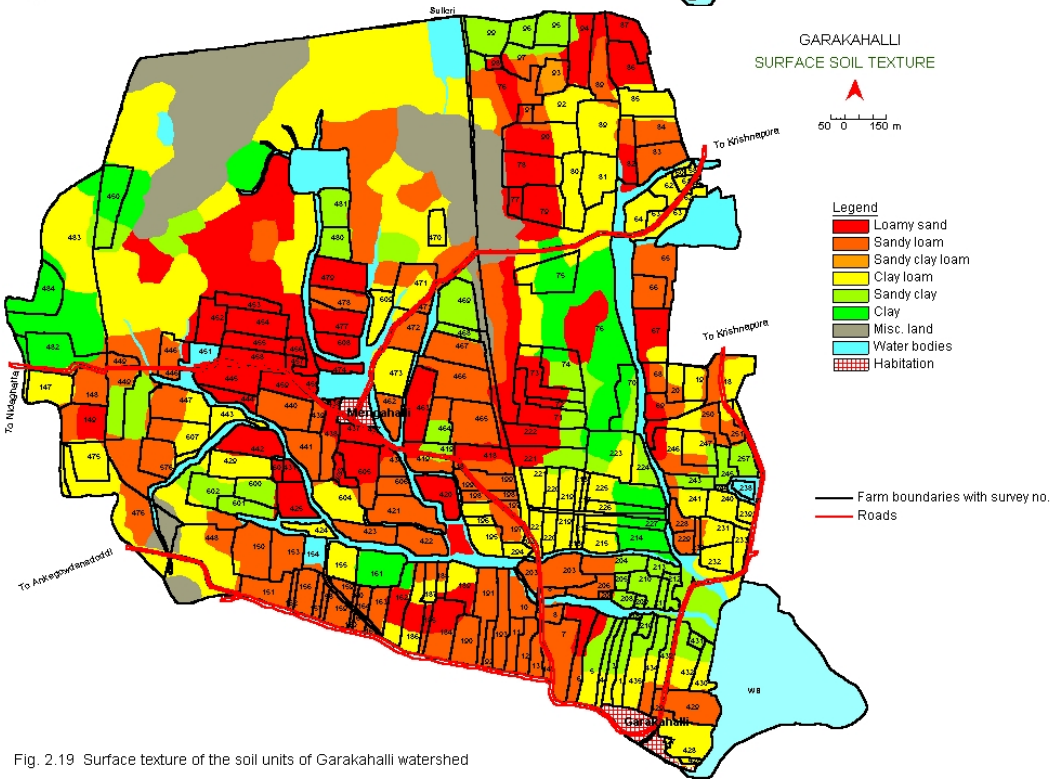

Fig. 2.19 Surface texture of the soil units of Garakahalli watershed

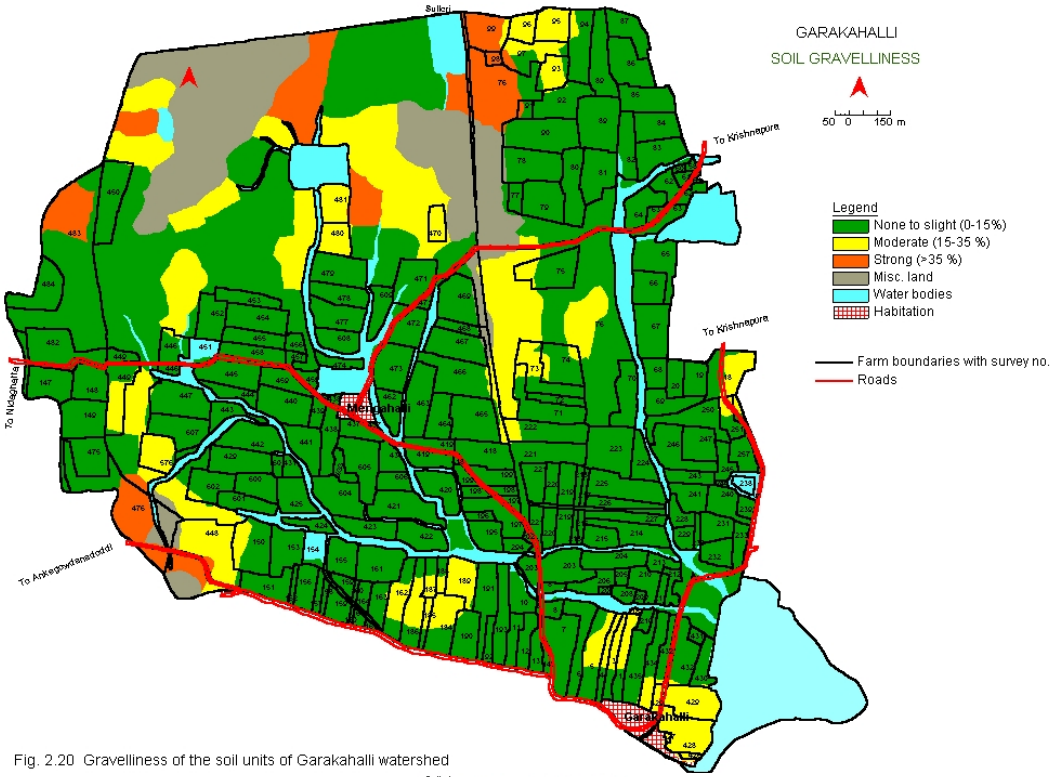

Fig. 2.20 Gravelliness of the soil units of Garakahalli watershed

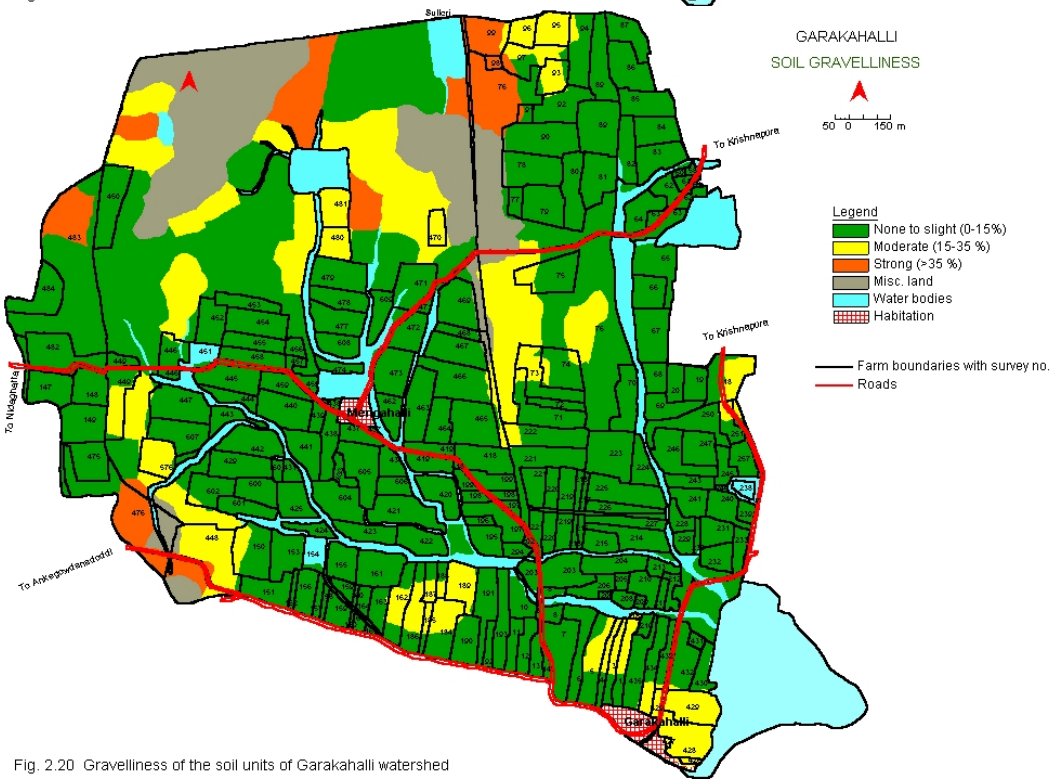

Fig. 2.20 Gravelliness of the soil units of Garakahalli watershed

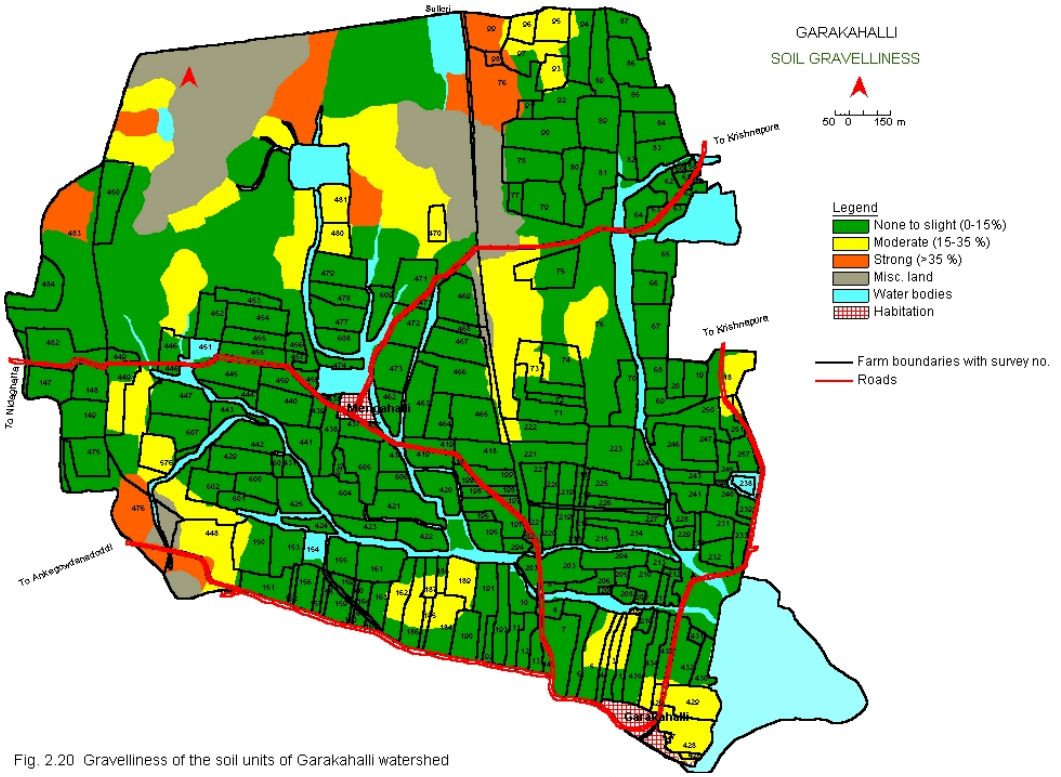

Fig. 2.20 Gravelliness of the soil units of Garakahalli watershed

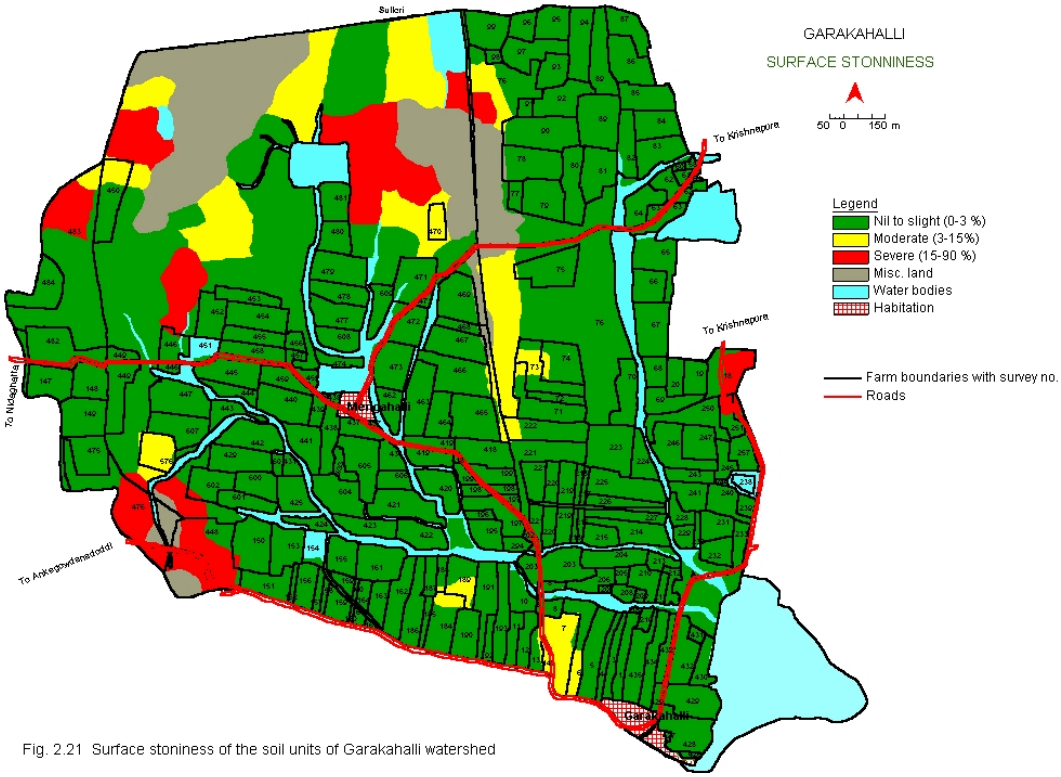

Fig. 2.21 Surface stoniness of the soil units of Garakahalli watershed

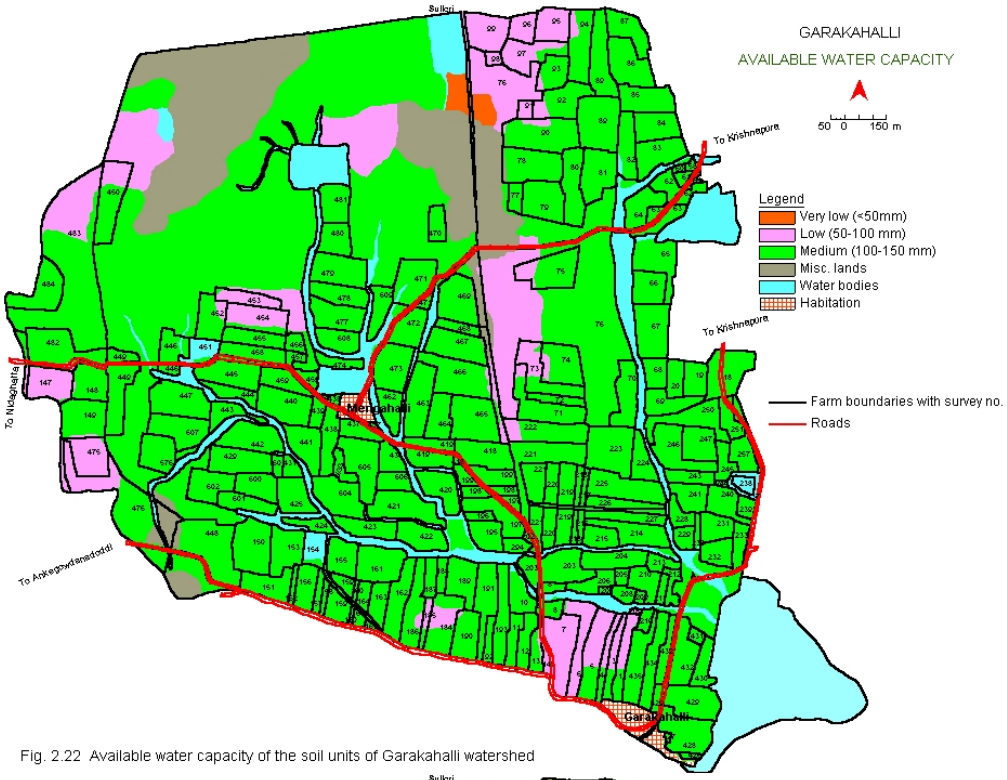

Fig. 2.22 Available water capacity of the soil units of Garakahalli watershed

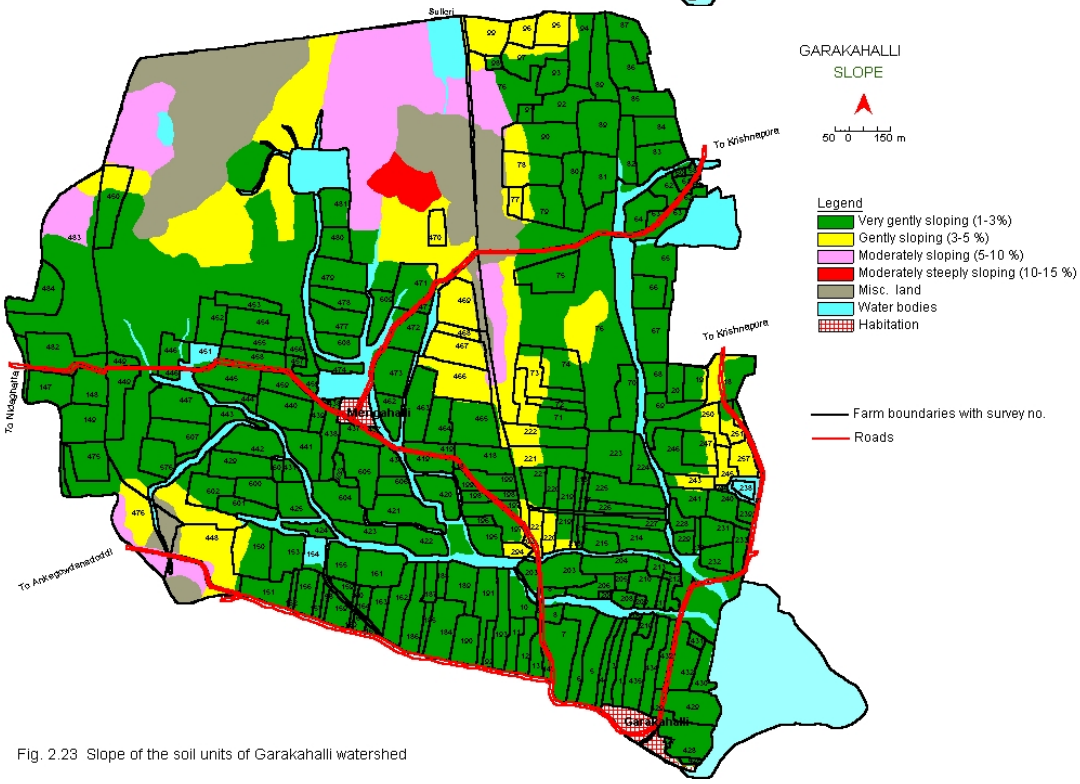

Fig. 2.23 Slope of the soil units of Garakahalli watershed

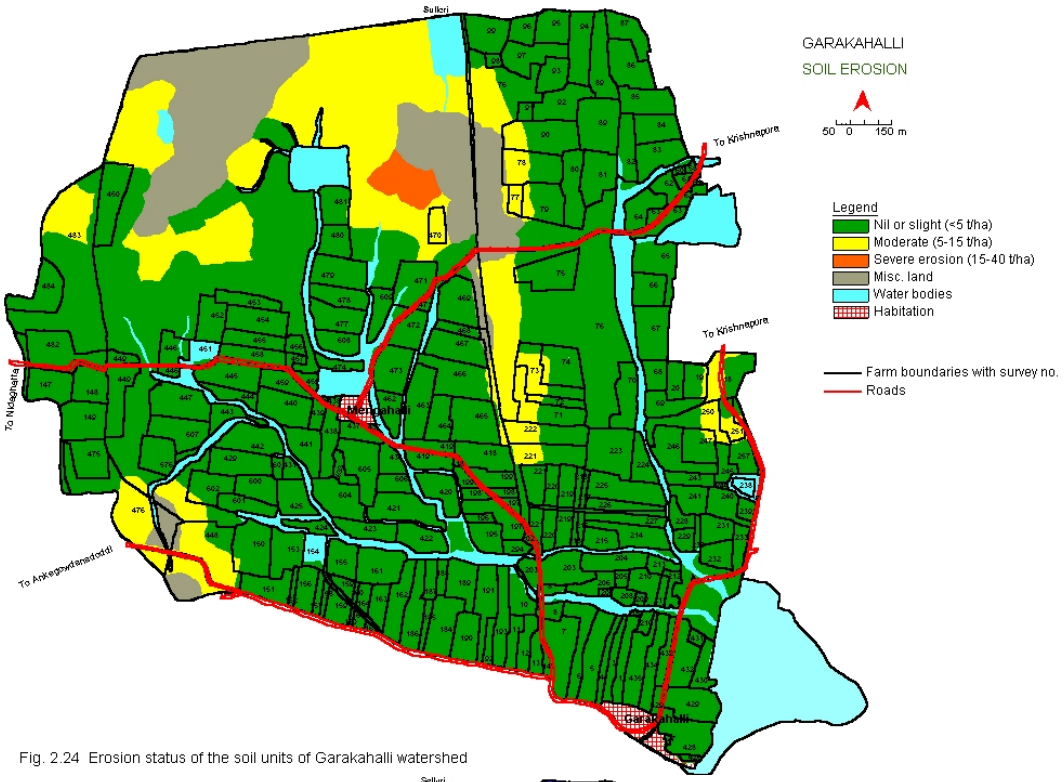

Fig. 2.24 Erosion status of the soil units of Garakahalli watershed

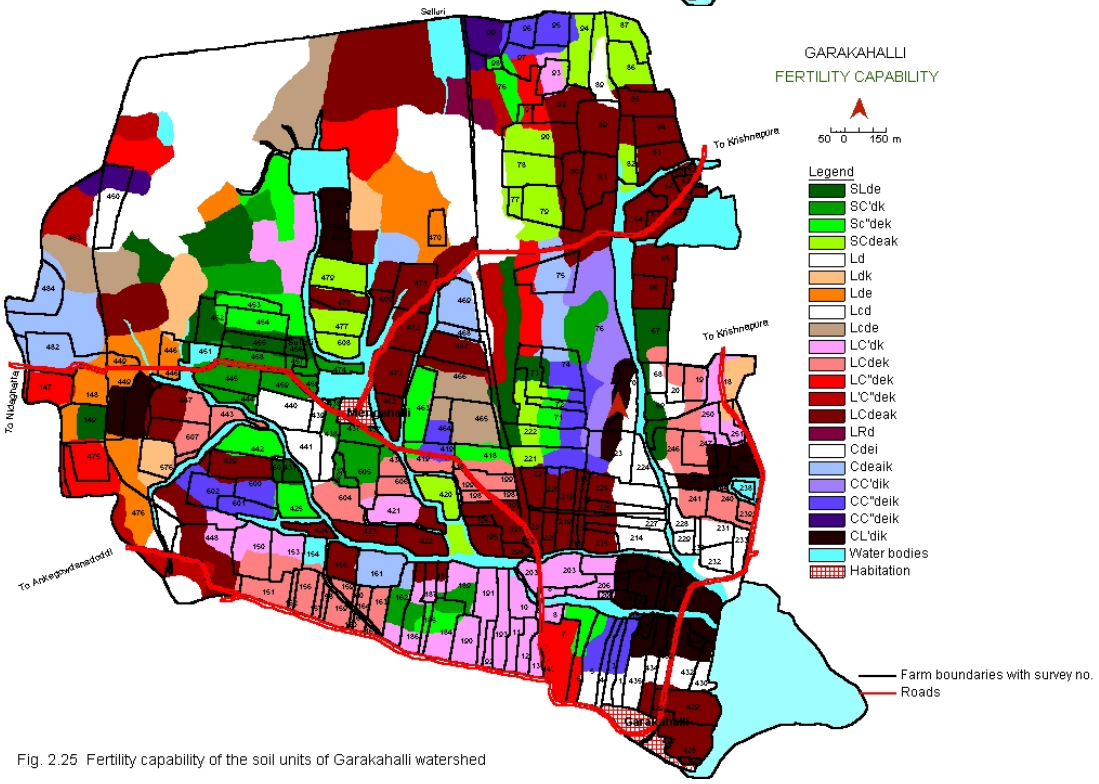

Fig. 2.25 Fertility capability of the soil units of Garakahalli watershed

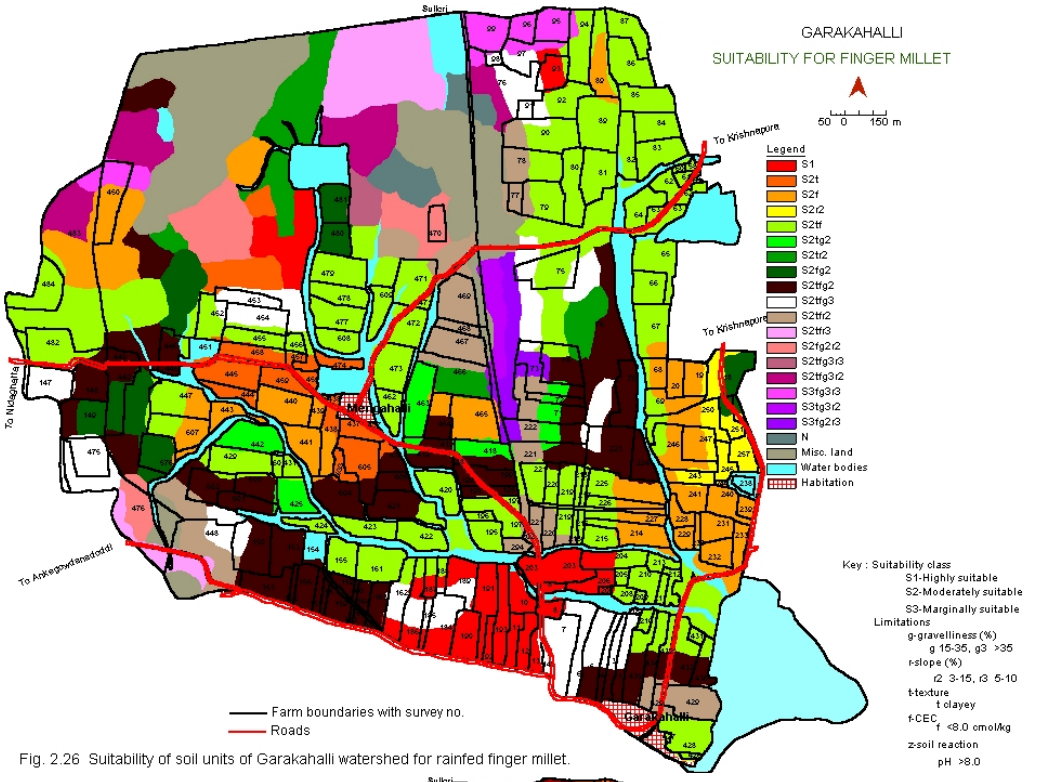

Fig. 2.26 Suitability of soil units of Garakahalli watershed for rainfed finger millet.

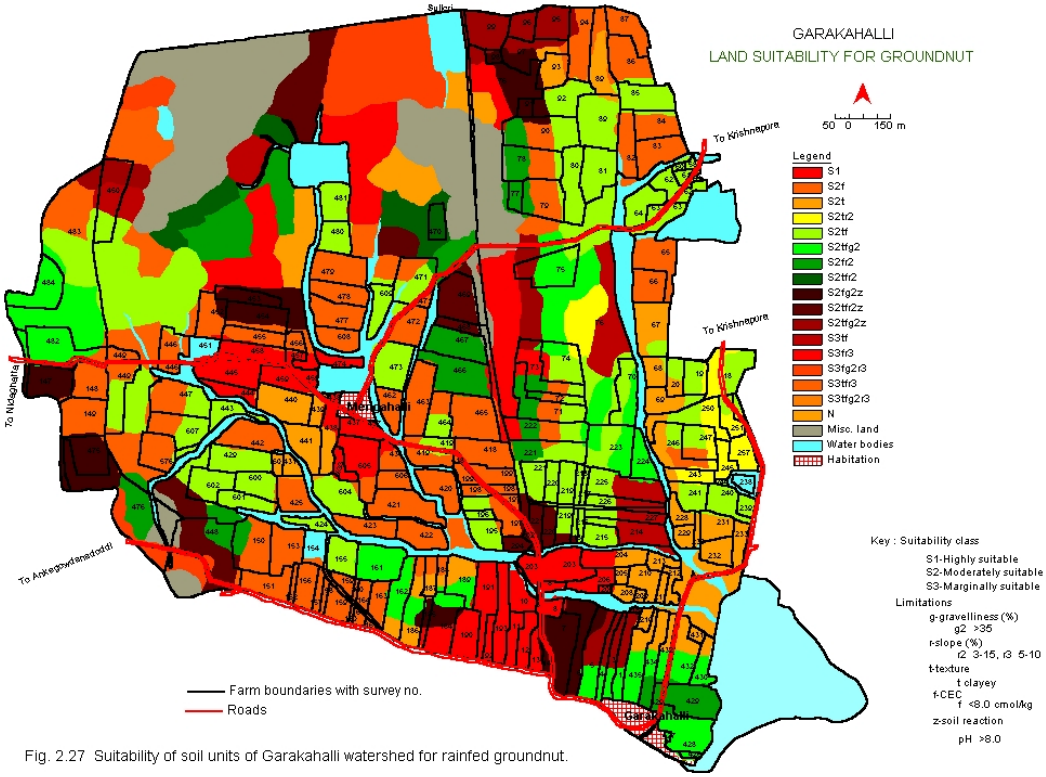

Fig. 2.27 Suitability of soil units of Garakahalli watershed for rainfed groundnut.

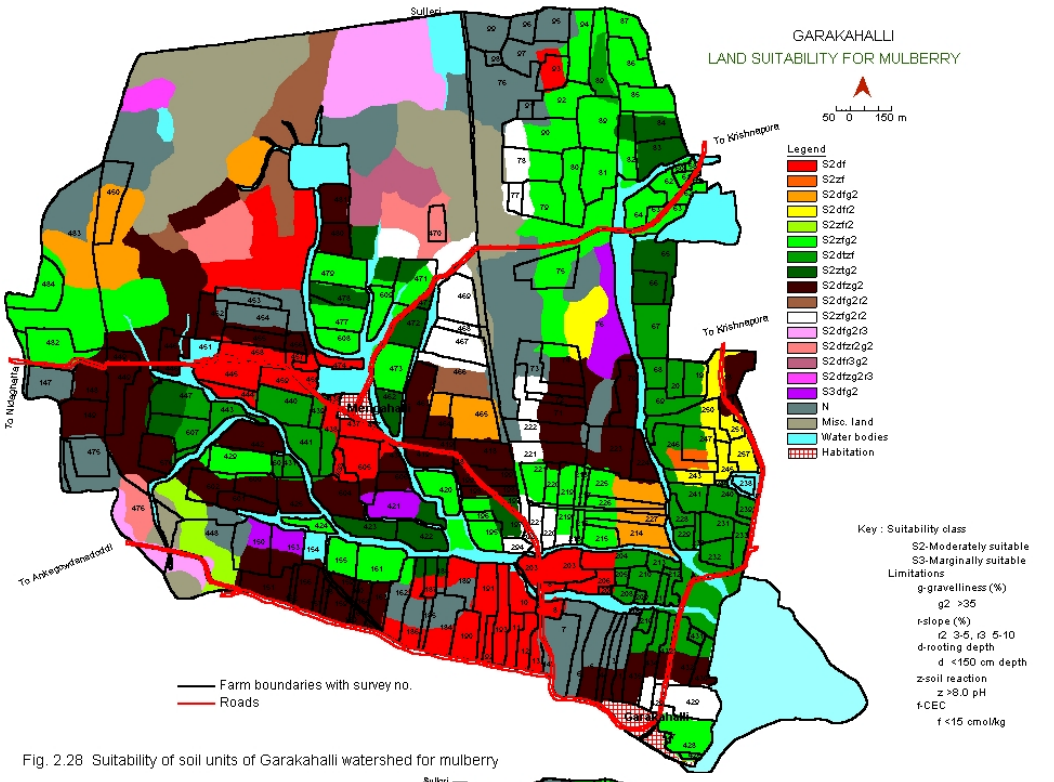

Fig. 2.28 Suitability of soil units of Garakahalli watershed for mulberry

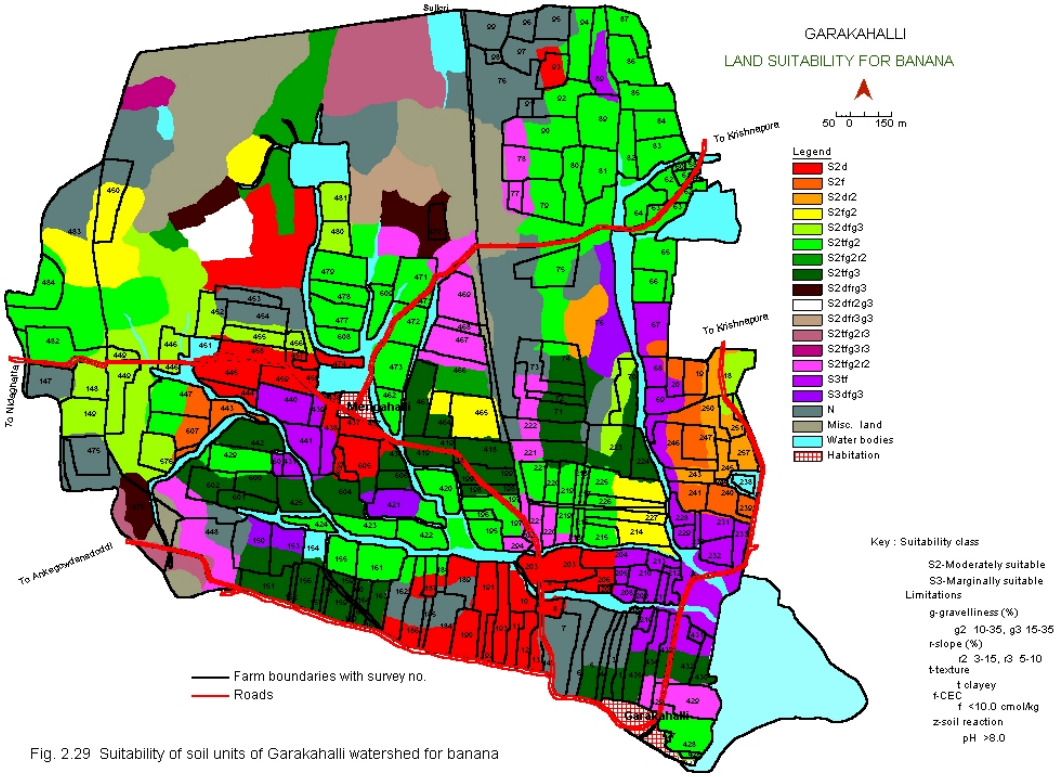

Fig. 2.29 Suitability of soil units of Garakahalli watershed for banana

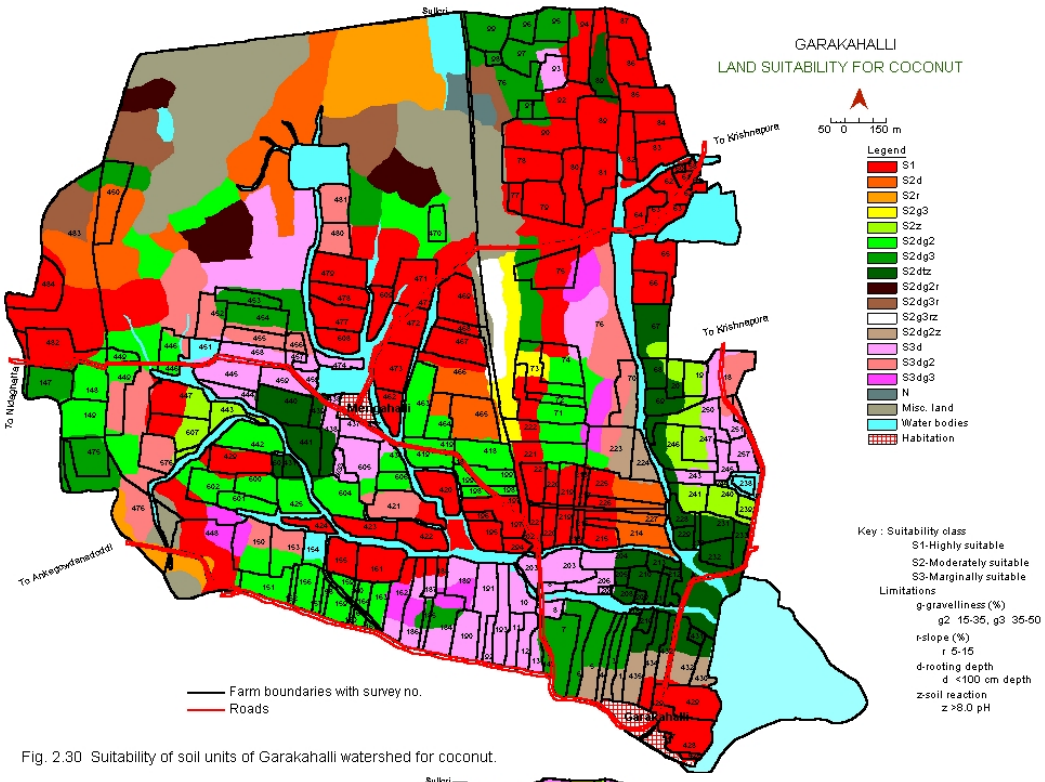

Fig. 2.30 Suitability of soil units of Garakahalli watershed for coconut.

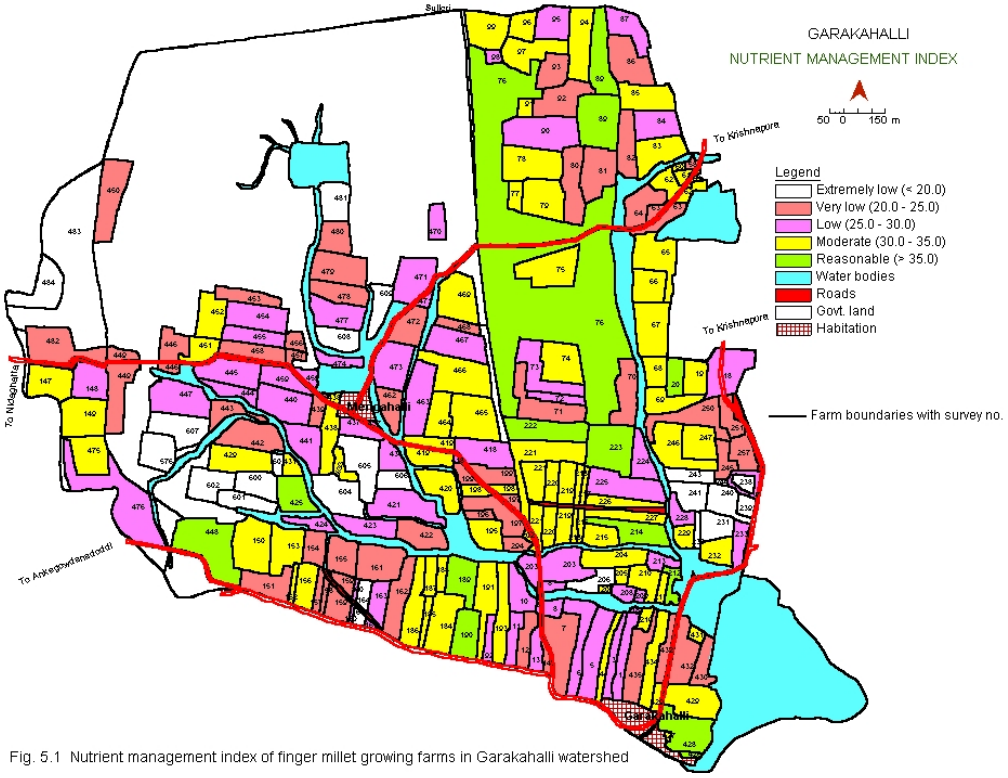

Fig. 5.1 Nutrient management index of finger millet growing farms in Garakahalli watershed

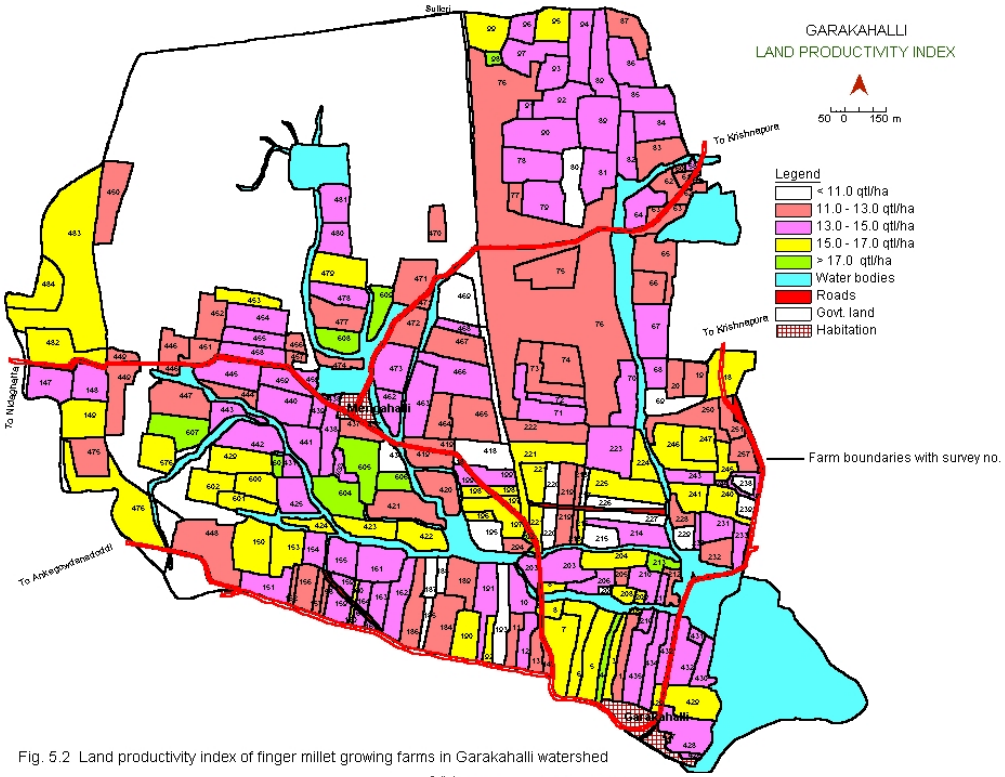

Fig. 5.2 Land productivity index of finger millet growing farms in Garakahalli watershed

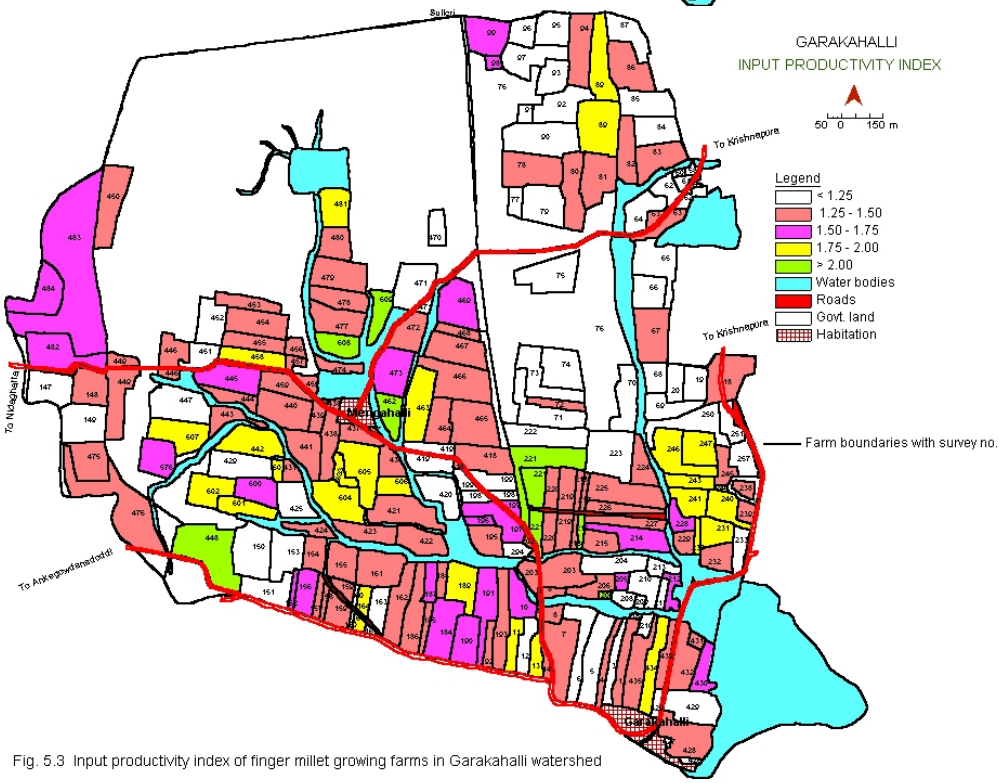

Fig. 5.3 Input productivity index of finger millet growing farms in Garakahalli watershed

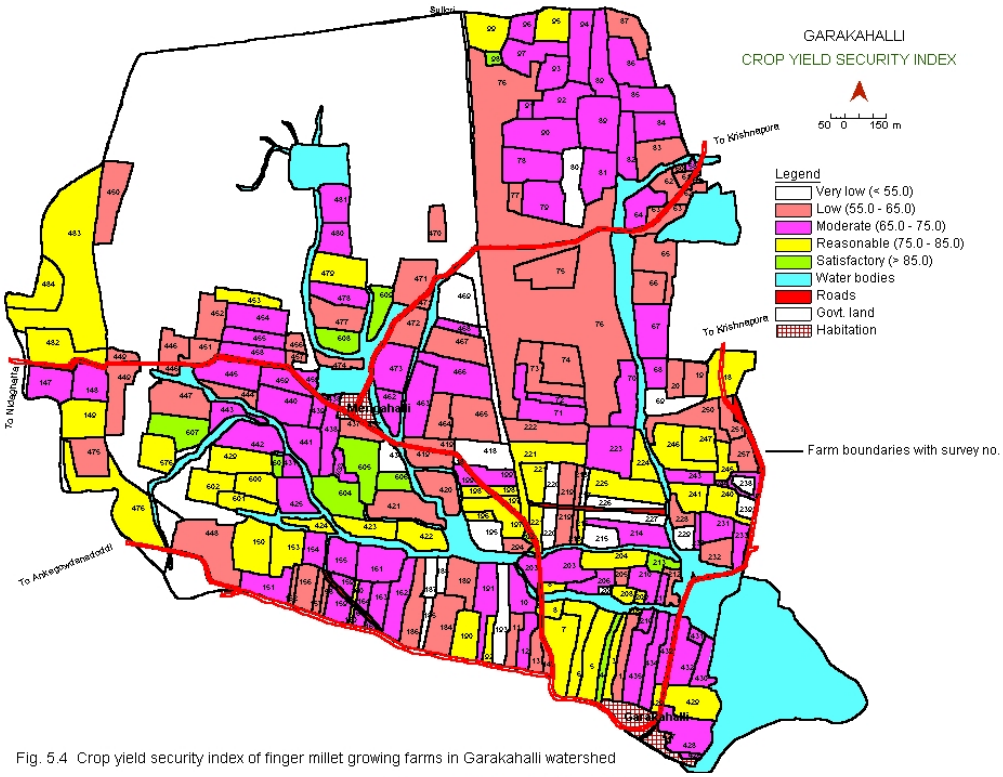

Fig. 5.4 Crop yield security index of finger millet growing farms in Garakahalli watershed

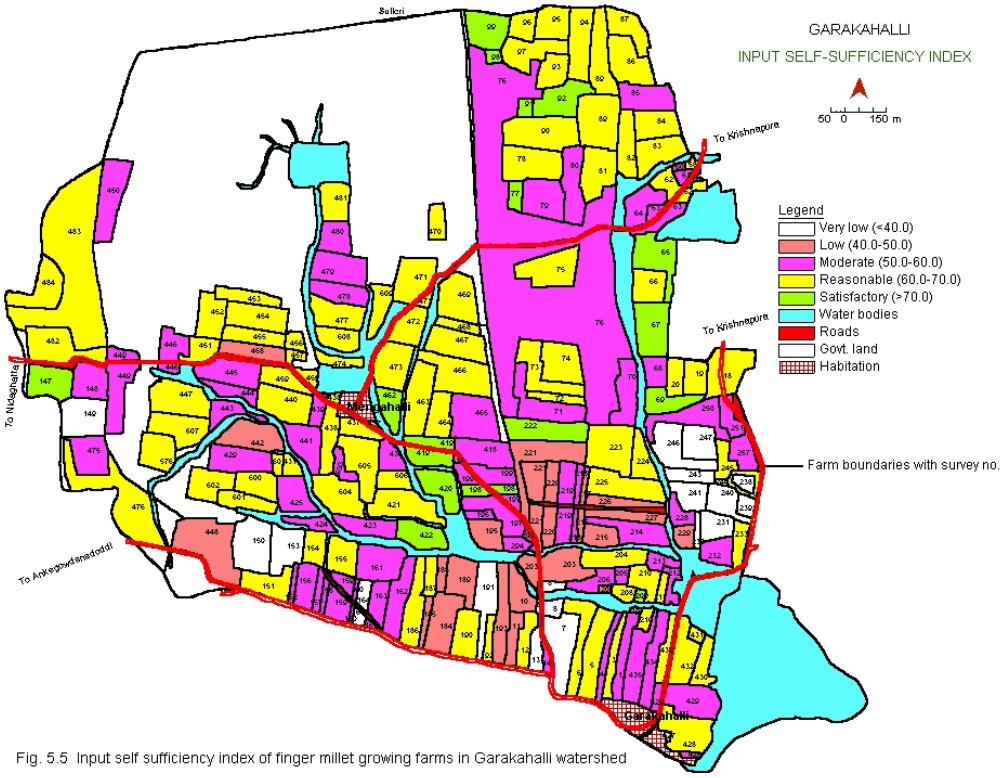

Fig. 5.5 Input self sufficiency index of finger millet growing farms in Garakahalli watershed

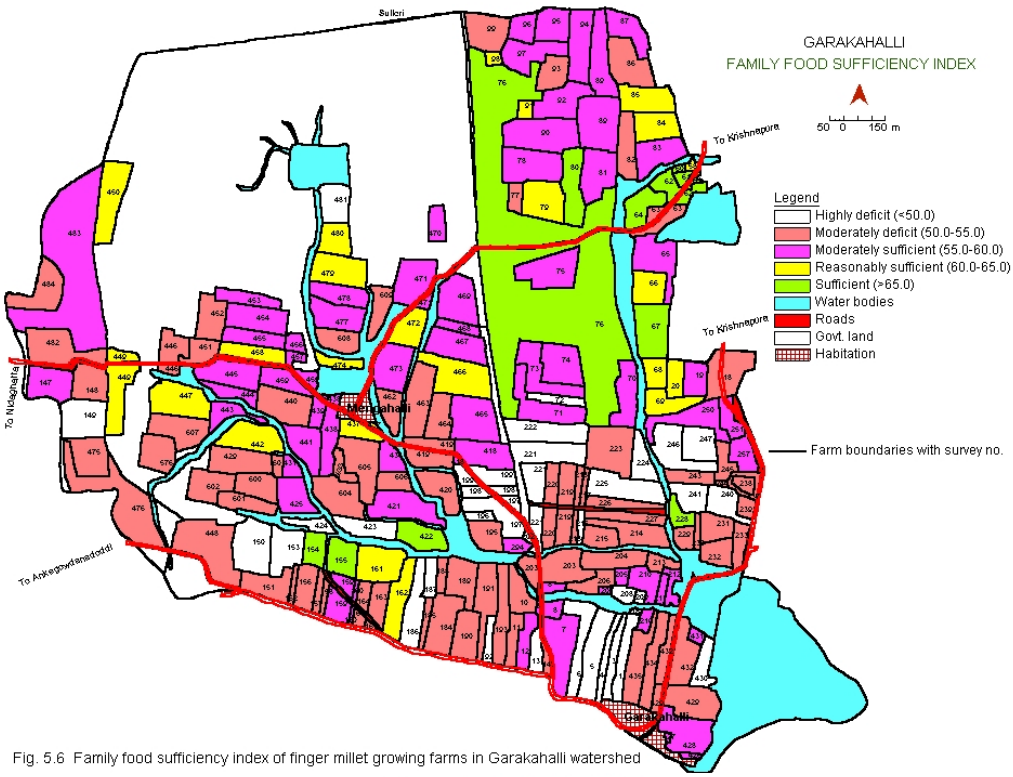

Fig. 5.6 Family food sufficiency index of finger millet growing farms in Garakahalli watershed

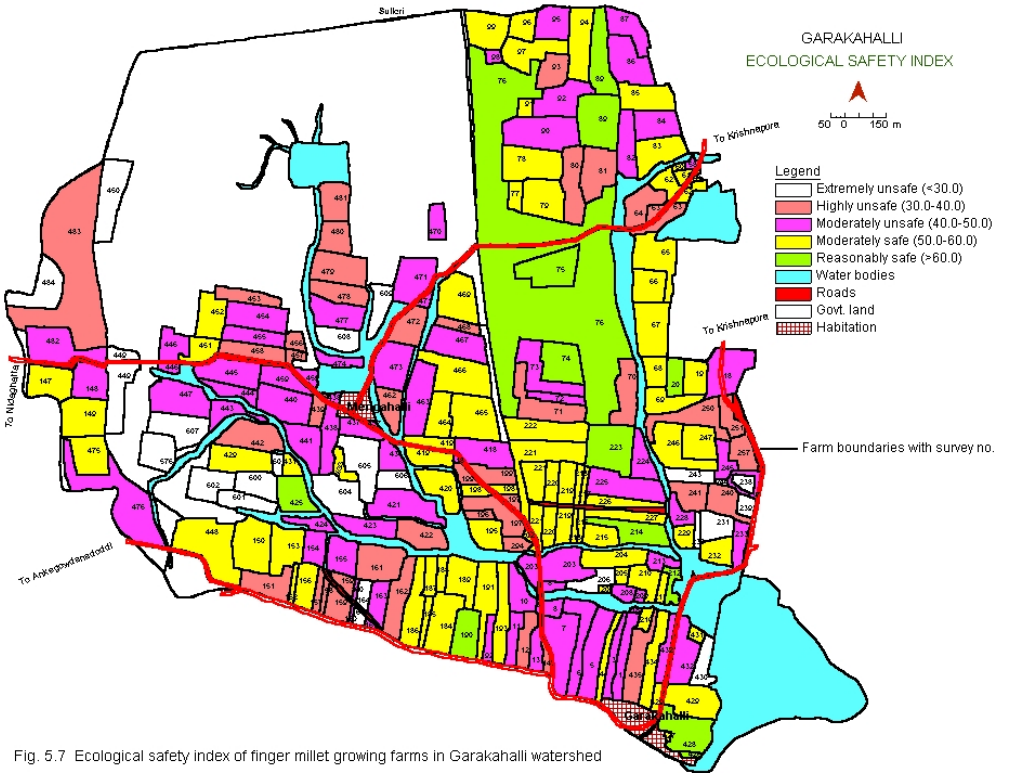

Fig. 5.7 Ecological safety index of finger millet growing farms in Garakahalli watershed

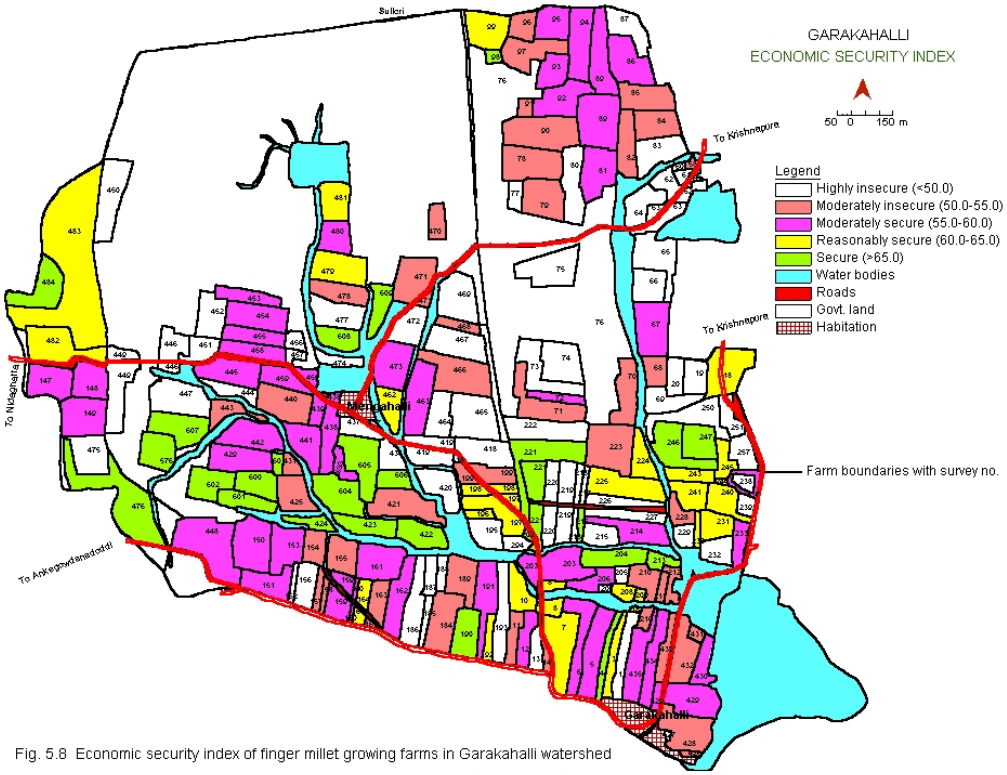

Fig. 5.8 Economic security index of finger millet growing farms in Garakahalli watershed

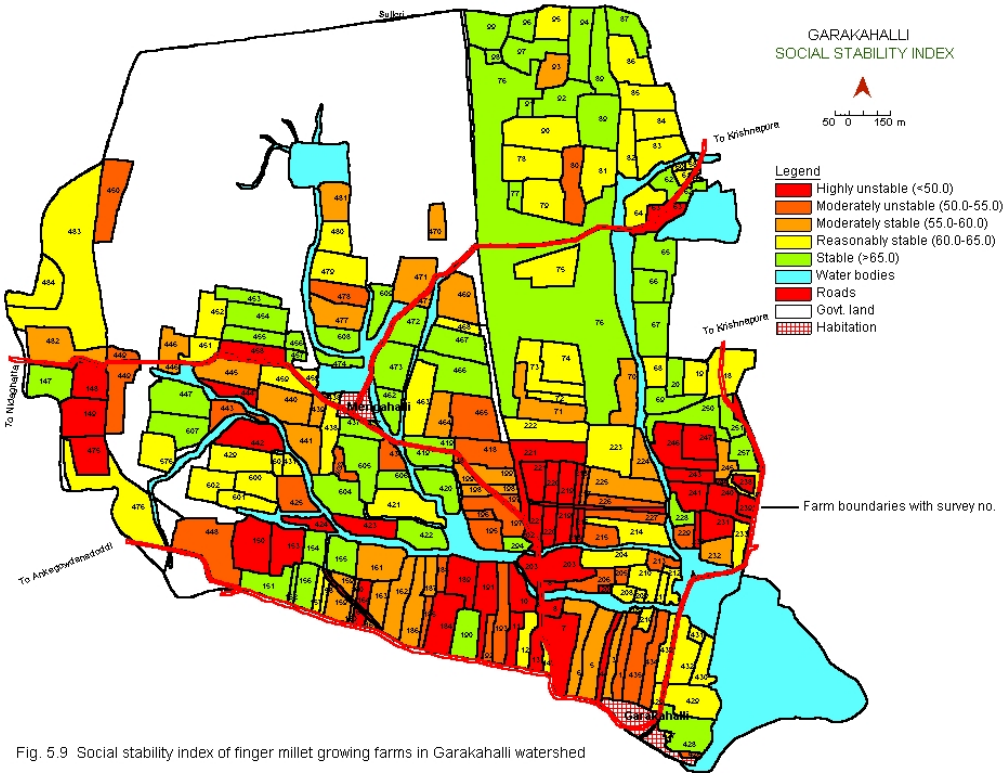

Fig. 5.9 Social stability index of finger millet growing farms in Garakahalli watershed

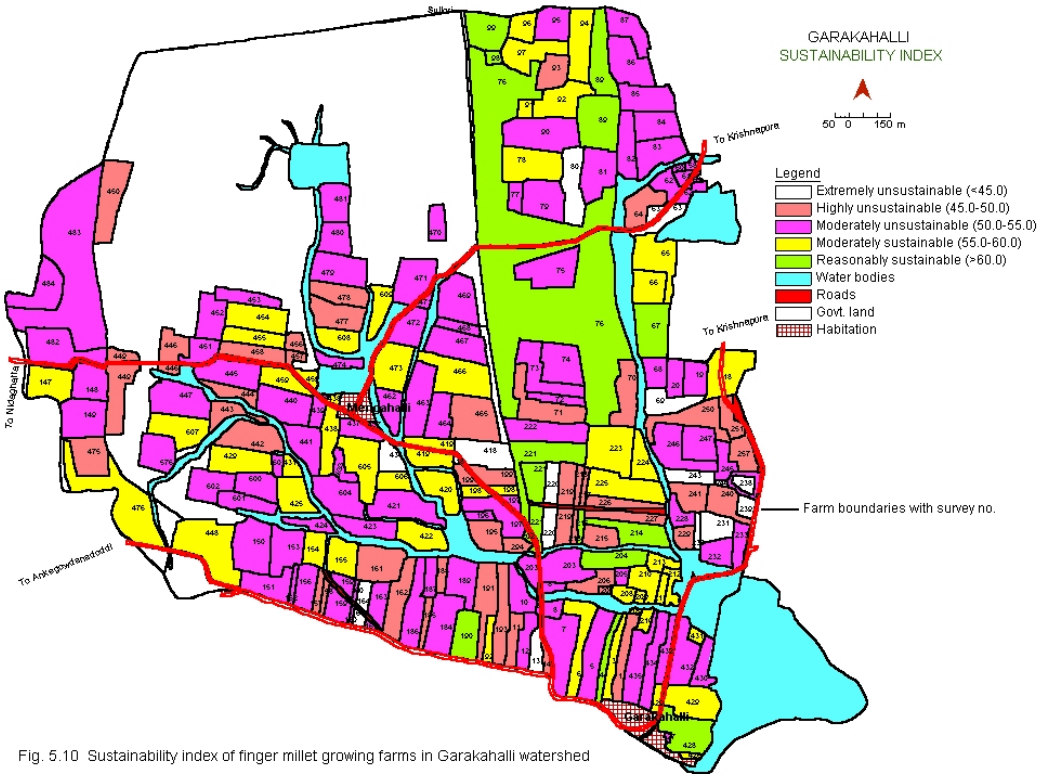

Fig. 5.10 Sustainability index of finger millet growing farms in Garakahalli watershed