Research Bulletin No: 9

ICARRCG

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S.Manivannan
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ICAR RESEARCH COMPLEX FOR GOA
(Indian Council of Agricultural Research)
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2007

Editorial & Production guidance and published by:
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Correct Citation *:* Manivannan, S. and Korikanthimath,V.S (2007) Soil and water conservation measures for sustainable production of cashew. Research Bulletin No: 9, ICAR Research Complex for Goa (Indian Council of Agricultural Research), Ela, Old Goa- 403 402, Goa, India

Technical assistance: Sidharth K. Marathe

Printed at: Sahyadri Offset System, Corlim, Ilhas, Goa -403 110

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FOREWORD

Cashew is the prominent perennial horticultural crop, which has been contributing to the Indian economy significantly. The history of trade can be traced back to first quarter of 20th century. The export touched a level of 1.14 lakh MT of cashew kernel worth Rs 2515 crores during 2005-2006. Although, the area under cashew cultivation is around 7.70 lakh hectares, about 40 per cent of the area has become low productive contributing to less than 20 per cent of the country's production. From the beginning of the eighth plan, about 2.20 lakh ha of the plantations have been planted with superior clones of high yielding varieties / hybrids. About 30 per cent of the area is still under bearing stage with the availability of large number of grafts of recommended and released elite varieties. Most of the cashew trees in Western Ghat regions were planted in hilly slopes without adopting soil and water conservation measures resulting in low productivity. It is a high time to take up the replanting programme with suitable soil and water conservation measures in those regions to increase the cashew production.

ICAR Research Complex for Goa, Old Goa has conducted field trials to develop and evaluate the different in-situ moisture conservation measures for cashew. Effects of these measures on runoff, soil loss, nutrient loss, soil characters, growth of cashew and yield of cashew nut have been quantified. Economic feasibility of different conservation measures was also analyzed and finally the most appropriate in-situ soil and water conservation measures for cashew were identified.

I am glad that the ICAR Research Complex for Goa has compiled the voluminous data collected over a period of six years and has come out with the recommendations for the soil and water conservation packages for cashew. I am confident that this research bulletin will be of great help and guidance to the farmers and development agencies in increasing the cashew production in the country in the near future.

A.K.Singh
Deputy Director General (NRM)
Indian Council of Agricultural Research

November, 2007

PREFACE

Cashew is the most important commercial crop of India with export of kernels earning foreign exchange worth Rs. 2514.8 crores during 2005-06. India is the largest importer, producer, processor, consumer and exporter of the cashew in the world. India occupies the largest area of the cashew crop. Cultivation of cashew in India confines mainly to the peninsular areas that includes Kerala, Karnataka, Goa and Maharashtra along the west coast and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal along the east coast. To a limited extent it is being cultivated in Chattisgarh, North Eastern States (Assam, Manipur, Tripura, Meghalaya and Nagaland) and Andaman & Nicobar Islands. Though India ranks first in area and production contributing 37 and 42 per cent of total world area under cultivation and production respectively, per hectare yield is very low (710 kg ha^{-1}). In Goa the mean productivity is still lower (466 kg ha^{-1}) than national average. One of the main constraints for low productivity is lack of *In-situ* moisture conservation measures in sloppy lands and subsequent moisture stress during the summer.

In order to explore the possibility higher productivity, the ICAR Research Complex for Goa, Old Goa conducted study on soil and water conservation measures for cashew by adopting different *In-situ* soil and water conservation measures. Two sets of trails were conducted by adopting two different spacing. Important results of the study on runoff, soil loss, nutrient loss, soil moisture content, growth of cashew up to 5th year, yield of cashew and yield of vegetative barriers were monitored, analyzed and reported in this technical bulletin. In addition, the economical feasibility of different conservation measures was worked out and reported along with suitable soil and water conservation measures for cashew crop.

We hope and look forward that this bulletin will be of immense use to the developmental agencies and policy makers of the State as well as central government and farming community to intervene and take appropriate steps to increase the cashew productivity.

Authors
S.Manivannan
V.S.Korikanthimath

November, 2007

Acknowledgement

The authors are greatful to Dr. Mangala Rai, Director General, ICAR & Secretary, DARE, Dr. J. S. Samra, former DDG (NRM) and Dr. A. K Singh, DDG (NRM), ICAR, New Delhi for their encouragement, suggestions and support in carrying out this research work . We experess our gratitude to Dr. P. Rethinam, Dr. T.V. R.S. Sharma, Dr. D.G. Dhandar and Dr. S. Edison who were the Agro-Eco system Directors (NATP-Coastal) for their necessary support to conduct this study from 2000 to 2003.

Our sincere thanks are due to former directors of ICAR Research Complex for Goa - Dr.D.G.Dhandar and Dr.P.G.Adsule for their guidance at the initiation of this research work.

We extend our gratitude to Dr.A.K.Sikka, Director, ICAR Research Complex for Eastern Region, Patna (Principal Investigator of the project from 2000 to 2002) for his guidance in planning the experiments.

Dr. M. Madhu, Senior Scientist, CSWCRTI, Regional centre, Ooty (Principal Investigator from 2002 to 2003), Co-Principal Investigators of the project - Shri.A.R.Desai, Scientist SG, Dr.B.L.Majunath, Senior Scientist, Smt.S.Priyadevi, Scientist SS and Shri.J.Ashokkumar, Scientist SS of ICAR Research Complex for Goa deserve our sincere appreciations.

Authors

S.Manivannan

V.S.Korikanthimath

Executive Summary

India is the largest producer, processor, consumer and exporter of the cashew in the world. India has a creditable record of earning sizeable foreign exchange by way of export of cashew kernels. Among the Agri-Horticultural commodities exported from India, cashew ranks the second position contributing 0.56 % of the total export earnings of the country during 2005-06. During the year 2005-2006, India could export 1,14,143 MT of cashew kernels valued at Rs.2514.8 crores. Though India ranks first in area and production contributing 37 and 42 per cent of total world area under cultivation and production respectively, per hectare yield is very low (710 kg ha^{-1}). In Goa the mean productivity is still lower (466 kg ha^{-1}) than national average. The major constraints for low productivity are (i) lack of maintaining optimum plant population per unit area of cashew orchard, (ii) lack of *In-situ* moisture conservation measures in sloppy lands and subsequent moisture stress during the summer and (iii) Majority of earlier established cashew plantations were raised by cashew seedling progenies instead of softwood grafts resulting in low productivity.

Most of the cashew gardens are in mid to high hill region and there are no conservation measures to retain the soil moisture for long time. One of the short-term strategies to achieve 10.00 lakh MT that can be absorbed by 1100 processing units established in the country is to increase per unit area productivity in the country. The best option available is to go for high density planting with suitable in-situ soil and water conservation measures instead of conventional cultivation method. Packages and practices of high density planting of cashew is well documented by National Research Centre for Cashew (NRCS). However, the information available on soil and water conservation measures for cashew crop is very limited. Keeping in view of above facts, the research project has been taken up at the ICAR Research Complex for Goa, Ela, Old Goa, Goa to develop suitable soil and water conservation measures for cashew crop in lateritic soil. The major objectives are to evaluate the effect of different bio-engineering measures on hydrological and soil characteristics, quantify the impact of bio-engineering measures on growth parameters and yield of cashew and analyze the economic feasibility of bio-engineering measures for cashew crop.

Two sets of experiments were conducted in different high density planting methods. One set of soil and water conservation measures evaluated under 4 m X 4 m spacing and other with 6 m X 6 m spacing. Field data on runoff, soil loss, nutrient loss, soil

moisture content, growth of cashew and yield parameters were recorded for six years period. Thus, collected data were pooled, analyzed and reported.

Continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* and staggered contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* reduced the runoff by 44.5 and 34.6 per cent, respectively under spacing of 4 m X 4 m cashew plantations. Similarly, continuous contour trenches with vegetative barrier of *Stylosanthes scabra* + *Gliricidia maculata*, staggered contour trenches with *Stylosanthes scabra* and *Gliricidia maculata* and crescent shape trenches with *Stylosanthes scabra* and *Gliricidia maculata* recorded runoff reduction of 46.3, 35 and 29.0 per cent, respectively in the field where cashew was planted at 6 m x 6m spacing.

Continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* and staggered contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* reduced the soil loss by 11.3 and 8.1 t ha^{-1} yr^{-1} in 4 m x 4 m cashew field. Similarly, continuous contour trenches with vegetative barrier of *Stylosanthes scabra* + *Gliricidia maculata* significantly reduced average soil loss (6.5 t ha^{-1}) followed by staggered contour trenches with *Stylosanthes scabra* and *Gliricidia maculata* (5.6 t ha^{-1}) and crescent shape trenches + *Stylosanthes scabra* and *Gliricidia maculata* (5.7 t ha^{-1}) in the plot where the cashew was planted at 6 m x 6 m spacing.

Continuous contour trenches with vegetative barriers was the best when compared to all other treatments as far as nutrient loss reduction was concerned. Staggered contour trenches with vegetative barriers were found as the next best treatment in reducing the nutrients loss under cashew crop. Highest soil and water conservation efficiency was observed in continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* (49.5 per cent) followed by staggered contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* (37.1 per cent) under 4 m X 4 m cashew plantations. Similarly, maximum soil and water conservation efficiency was observed in continuous contour trenches with *Stylosanthes scabra* + *Gliricidia maculata* (62.9 per cent) followed by staggered contour trenches with *Stylosanthes scabra* + *Gliricidia maculata* (51.3 per cent) in the plot where cashew was planted at 6 m x 6 m spacing.

Soil and water conservation measures increase and retain the soil moisture till the month of May. Continuous contour trench with vegetative barriers was found to be the best conservation measure to retain soil moisture for longer duration after cessation of monsoon. Alternatively, the staggered contour trench with vegetative barrier was found to be better in retaining soil moisture.

All the conservation measures significantly increased the growth and yield of cashew. Continuous contour trenches and staggered contour trenches with vegetative barriers recorded the maximum plant growth and yield. Total cashew nut yield of 7.72, 14.21 and 18.1 q ha^{-1} were recorded in treatment comprising of continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* during fourth, fifth and sixth years, respectively under 4 m X 4 m cashew plantations. The total cashew nut yield of 6.80, 3.50 and 5.20 q ha^{-1} were recorded in treatment comprising of continuous contour trenches with *Stylosanthes scabra* + *Gliricidia maculata* during fourth, fifth and sixth years, respectively under 6 m X 6 m plantations. Maximum NPW of Rs. 4, 61, 820 per ha was obtained under cashew cultivation with continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* followed by Rs. 4,08, 090 per ha under cashew cultivation with staggered contour trenches *Stylosanthes scabra* and *Vetiveria zizanioides.* Maximum NPW of Rs. 1, 64, 900 per ha was obtained under cashew cultivation with continuous contour trenches with *Stylosanthes scabra* + *Gliricidia maculata* followed by Rs. 1,27,190 per ha under cashew cultivation with staggered contour trenches *Stylosanthes scabra* + *Gliricidia maculata*. Higher benefit cost ratio and Internal rate of return were obtained under the continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* (6.87 and 20 per cent, respectively) followed by staggered contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* (6.82 and 18 per cent, respectively) under 4 x 4 m cashew plantation. Similarly, BCR and IRR were higher under the continuous contour trenches with *Stylosanthes scabra* and *Glyricidia maculata* (5.07 and 13 per cent, respectively) followed by the staggered contour trenches with *Stylosanthes scabra* and *Gliricidia maculata* (4.64 and 12.5 per cent, respectively) under 6 m X 6 m cashew plantations.

In summary, it could be concluded that the continuous contour trenches with vegetative barriers was the best as compared to all other treatments for runoff, soil loss and nutrient loss reduction. Staggered contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* was the alternative measure for reduction of runoff and soil loss for cashew land use. Additional income could be generated from the vegetative barriers, which can be used as either fodder or biomass for mulching during the initial period of cashew plantation by adapting the bio-engineering measures. Continuous contour trenches with vegetative barriers and staggered contour trenches with vegetative barriers were found economically viable and these technologies are recommended for adoption in the cashew plantations in hilly terrain.

Glossary

BCR	:	Benefit-cost ratio
C mol (p^+) kg^{-1}	:	Centi mole proton per kilogram
CCT	:	Continuous contour trenches
CST	:	Crescent shape trenches
GT	:	Graded trenches
HMT	:	Half moon terraces
IRR	:	Internal rate of return
MAP	:	Months after planting
NPW	:	Net present worth
SCE	:	Soil conservation efficiency
SCT	:	Staggered contour trenches
SET	:	Semi elliptical trenches
SWCE	:	Soil and water conservation efficiency
VB	:	Vegetative barriers
WCE	:	Water conservation efficiency

Contents

1. INTRODUCTION

Cashew (*Anacardium occidentale L.)* a native of Eastern Brazil was introduced to India by the Portuguese in 16th century. The first introduction of cashew in India was made in Goa from where it spread to other parts of the country. In the beginning it was mainly considered as a crop for afforestation and soil conservation to check soil erosions. The nuts, apple and other by-products of this crop are of commercial importance. Though its commercial exploitation commenced since the early 60's, marginal lands and denuded forests were the areas set apart for the cashew plantation development. Due to the absence of high yielding varieties and appropriate multiplication techniques, indiscript seeds and seedlings were used for planting purposes. Because of its high adaptive ability and acclimatization in wide range of agro climatic conditions, it has become a crop of high economy and attained the status of an export-oriented commodity of the country.

India is the largest producer, processor, consumer and exporter of the cashew in the world. India has a creditable record of earning sizeable foreign exchange by way of export of cashew kernels. Among the Agri-Horticultural commodities exported from India, cashew ranks the second position contributing 0.56 % of the total export earnings of the country during 2005-06. The trade history dates back to first quarter of 20th century with export of 20 MT to a steady level of 1.00 lakh MT of cashew kernel valued at Rs 2500 crores during 1999-2000. During the year 2005-2006, India could export 1,14,143 MT of cashew kernels valued at Rs.2514.8 crores. USA, Netherlands, UK, Japan, UAE, France, Canada, Saudi Arabia, Singapore, Italy, Germany, Austria, Israel and Spain are the major international buyers of Indian Cashews. India occupies the largest area of the cashew crop. Cultivation of cashew in India confines mainly to the peninsular areas that includes Kerala, Karnataka, Goa and Maharashtra along the west coast and Tamil Nadu, Andhra Pradesh, Orissa and West Bengal along the east coast. To a limited extent it is being cultivated in Chattisgarh, North Eastern States (Assam, Manipur, Tripura, Meghalaya and Nagaland) and Andaman & Nicobar Islands.

However, in spite of 7.70 lakh hectares of cashew, major portion (about 40 %) has become senile contributing less than 20 per cent of total production in our country. Of these, 2.00 lakh ha of the plantations developed from the beginning of 8th plan alone have been with superior clones of high yielding varieties / hybrids. About 30 per cent of the area is still under bearing stage with the availability of large number of grafts of recommended and released elite varieties, it is a high time to take up the replanting programme with soil and water conservation measures in the country to replace the senile plantations.

Though India ranks first in area and production contributing 37 and 42 per cent of total world area under cultivation and production respectively, per hectare yield is very low (710 kg ha^{-1}). In Goa the mean productivity is still lower (466 kg ha^{-1}) than national average. The major constraints for low productivity are (i) lack of maintaining optimum plant population per unit area of cashew orchard, (ii) lack of *in situ* moisture conservation measures in sloppy lands and subsequent moisture stress during the summer and (iii) Majority of earlier established cashew plantations were raised by cashew seedling progenies instead of softwood grafts resulting in low productivity. Most of the cashew gardens are in mid to high hill region and there are no conservation measures to retain the soil moisture for long time.

One of the short-term strategies to achieve 10.00 lakh MT that can be absorbed by 1100 processing units established in the country is to increase per unit area productivity in the country. The best option available is to go for high density planting with suitable *in-situ* soil and water conservation measures instead of conventional cultivation method. National Research Center for Cashew, Puttur, Karnataka and its centres of All India coordinated Research Project on cashew located in West and East Coast regions have conducted the trials on spacing / plant density by adopting various plant population densities /unit area (156 to 2500 trees ha^{-1}). Packages and practices of high density planting of cashew is well documented by National Research Centre for Cashew (NRCS). However, the information available on soil and water conservation measures for cashew crop is very limited.

Keeping in view of above facts, the research project has been taken up at the ICAR Research Complex for Goa, Ela, Old Goa, Goa to develop suitable soil and water conservation measures for cashew crop in lateritic soil with following objectives:

1. Evaluate the effect of different bio-engineering measures on runoff, soil and nutrient losses and soil characteristics in hilly slope lands with cashew crop.
2. To quantify the impact of bio-engineering measures on growth parameters and yield of cashew.
3. To analyze the economic feasibility of bio-engineering measures on cashew crop.

2. DESCRIPTION OF THE STUDY AREA

2.1. Study area

The State of Goa covers an area of 3702 sq. km and accounts for about one per cent of the total geographical area of the country. Majority of the soil series are coarse to medium textured and well - drained with poor water holding capacity. Plantation crops like cashew, mango, arecanut, coconut etc. are predominantly occupying the steep slopes of lower coastal ghats and central undulating uplands of Goa. Many of the hilly areas in Goa are practically denuded and continue to be so due to heavy rainfall. With the result of erosion a large quantity of the fertile soil is eroded and transported from the fields. Most of the hilly areas in Goa are under perennial horticultural crops with cashew as predominant plantation crop, which is occupying an area of 54,858 ha. The present study was conducted at Research Farm of ICAR Research Complex for Goa of North Goa district of Goa State, India.

2.2. Location and relief

The experimental site lies in between 15 29' 28" North latitude and 73° 55' 14" East longitudes and located 69 M above mean sea level (MSL). The slope of the experimental site varies from 11 at lower reaches to 25 per cent at upper reaches. The mean slopes of the experimental area for experiment I and II are 19 and 14 per cent, respectively.

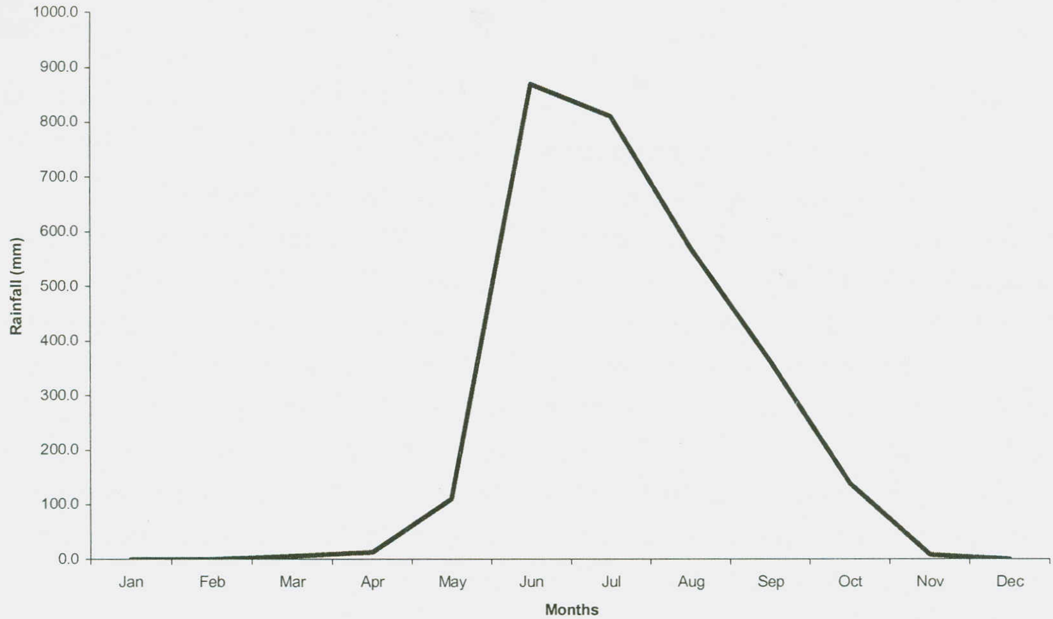
2.3. Climate

The study area has a warm tropical climate with an average annual temperature of 27.9° C. The soil temperature regime is iso-hyperthermic. An average rainfall of 2888.5 mm spread over 122 rainy days per annum is received. The distribution of rainfall with uni-model distribution as given in Table 2.1.indicates

Table 2.1. Distribution pattern of rainfall

Season	Amount of rainfall (mm)	Percent of annual rainfall (mm)
South-West Monsoon (June - September)	2611.0	90.4
Post monsoon showers (October - November)	147.6	5.1
Winter and summer showers (December - March)	7.1	0.2
Pre-monsoon showers (April- May)	122.8	4.3
	2888.5	**100.0**

Fig. 2.1 Distribution of mean monthly rainfall



that South - West monsoon, contributes major part of rainfall (90.4 %). June and July months receive the maximum of 58 per cent of annual rainfall (Fig. 2.1). Maximum temperature of 35 ° C during the months of April - May and lowest temperature of 19.5 ° C during December - January has been observed. A mean monthly summary of meteorological data for the study area is presented in Table 2.2. Maximum bright sunshine has occurred for 9.9 hours in February and lowest of 2.1 hours in July. Mean annual total evaporation is 1306 mm.

2.4. Soil pattern

Soil series comprise moderately deep well drained clay loam and gravelly clay soils developed on laterite (Oxysols). They have reddish brown medium acid gravelly clay loam A-horizon and dark red medium acid clay loam and gravelly clay B-horizon. The available water holding capacity in solum depth was moderately low. The soil of the experimental site was acidic with pH of 5.4 to 5.6 and EC of 0.10 to 0.14 dS m^{-1} and CEC ranging from 11.8 to 12.7 C mole (p^{+}) kg^{-1} (Table 2.3).

Better organic carbon content (0.79 to 1.11 per cent) was observed in the experimental site. Macro and micronutrient status of the soil at different depths in the experimental site is furnished in Table 2.4. The available nitrogen and phosphorus content in the soil was low (44 to 107 and < 15 kg ha^{-1}, respectively) while available potassium was medium (128 to 226 kg ha^{-1}). Soil at the experimental site was with less clay content and more sand and gravel content. The gravel content of the soil varied from 41 to 45 per cent (Table 2.5).

Table 2.2. Mean monthly climatic data of ICAR Research Complex, Old Goa

Month	Temperature (°C)			Relative Humidity (%)		Sunshine (hr / day)	Evaporation (mm/day)
	Max.	Min.	Mean	I (7.34 Hrs)	II (14.34 hrs)		
January	33.7	19.4	26.5	82.4	37.2	9.1	4.5
February	34.6	20.2	27.4	85.4	40.6	9.9	5.3
March	34.5	22.9	28.7	90.7	51.7	9.0	4.4
April	35.0	24.8	29.9	84.7	53.3	9.4	5.0
May	35.2	25.9	30.5	84.3	56.0	8.1	5.0
June	31.1	24.5	27.8	93.2	79.8	3.2	2.2
July	29.7	24.2	26.9	94.4	83.2	2.1	2.0
August	29.5	23.9	26.7	95.2	82.3	3.1	2.6
September	30.2	23.6	26.9	94.9	76.1	4.8	2.6
October	32.8	23.5	28.1	90.9	63.8	7.1	3.0
November	34.0	21.9	27.9	77.1	43.0	8.3	3.5
December	34.0	19.5	26.8	74.6	35.9	9.3	2.9
Mean	**32.9**	**22.9**	**27.9**	**87.3**	**58.6**	**7.0**	**3.6**

Table 2.3. Physio - chemical properties of soil

Soil depth (cm)	pH	EC (dS m^{-1})	CEC (C mole (p^+) kg^{-1})
0 -30	5.6	0.14	12.7
30- 60	5.5	0.12	11.8
60 - 90	5.4	0.10	11.8

Table 2.4. Nutrient status of soil in the experimental site at different depths

Soil Depth (cm)	OC (per cent)	N (kg ha^{-1})	P (kg ha^{-1})	K (kg ha^{-1})	Zn (ppm)	Fe (ppm)	Mn (ppm)	Cu (ppm)
0 -30	1.10	107.65	13.33	226.20	0.65	23.99	15.78	0.58
30 -60	0.90	80.93	11.10	157.30	0.68	24.11	16.51	0.55
60 -90	0.79	43.93	10.20	128.30	0.71	25.90	17.20	0.54

Table 2.5. Soil aggregates of experimental site at different depths

Soil depth (cm)	Clay (%)	Very fine sand (%)	Fine sand (%)	Medium sand (%)	Coarse sand (%)	Very coarse sand (%)	Gravel (%)
0 -30	1.7	2.7	1.8	13.1	13.4	22.8	44.4
30 -60	1.9	2.8	1.9	13.2	14.1	22.9	43.2
60 -90	2.0	2.8	2.0	13.9	14.5	23.5	41.3

3. METHODOLOGY

This chapter deals with details of conservation measures, layout of experiment, different soil and water conservation measures adopted and the analytical tools / methods used for monitoring runoff, soil and nutrient loss and economic analysis.

3.1. Details of experiments

Two sets of experiments were conducted in different high density planting methods. One set of soil and water conservation measures evaluated under 4 m X 4 m spacing and other set with 6 m X 6 m spacing.

3.1.1. Experiment I

The experimental area was divided into six large size runoff plots of 75 x 17.5 m each (Fig. 3.1). In these plots, five types of bio - engineering measures were imposed in five plots and the remaining one plot was kept as control plot without any conservation measures to compare the treatment effects. The details of soil and water conservation treatments imposed are furnished in Table 3.1. Cashew variety Goa -1 was planted at a spacing of 4 m x 4 m (high density cropping model) in squared pattern. The crop was planted in the month of June 2001, before the onset of monsoon and cultivated fully under rainfed condition.

3.1.2. Experiment II

In this experiment, each plot had the dimensions of 75 x 22 m (Fig. 3.2). In these plots, three types of bio-engineering measures were imposed in three plots and one plot was with biological measures alone and the other plot was kept as control (without any conservation measures) to compare the treatment effects. The details of soil and water conservation treatments imposed are furnished in Table 3.2. Cashew variety Goa-1 was planted at a spacing of 6 m x 6 m in squared manner. The crop was planted in the month of June 2001 and cultivated fully under rainfed condition.

Table 3.1. Details and specifications of soil and water conservation measures imposed on cashew with 4 m X 4 m spacing

Treatments	Specification
T_1- Half moon terraces with *Stylosanthes scabra* and *Vetiveria zizanioides* (HMT + VB)	The semi-circular terraces were made down stream side of the plant at a distance of 1.5 m radius. Inward slope was maintained and two rows of *Stylosanthes scabra* followed by one row of *Vetiveria zizanioides* at a spacing of 50 cm were planted at the edge of the terrace.
T_2 – Continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* (CCT + VB)	The trenches for field length with top width of 0.45 m, bottom width of 0.30 m and depth of 0.45 m were made continuously along the contour at vertical interval of 1 m. Two rows of *Stylosanthes scabra* followed by one row of *Vetiveria zizanioides* at a spacing of 50 cm were planted as vegetative barriers on the down stream side of the trench bund.
T_3 – Graded trench with *Stylosanthes scabra* and *Vetiveria zizanioides* (GT + VB)	The trenches for field length with top of 0.45 m, bottom width of 0.30 m and depth of 0.45 m were made with 1 per cent grade. Two rows of *Stylosanthes scabra* followed by one row of *Vetiveria zizanioides* at a spacing of 50 cm were planted as vegetative barriers on the down stream side of the trench bund.
T_4- Staggered contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* (SCT + VB)	The trenches of length of 2m, top width of 0.45 m, bottom width of 0.30 and depth of 0.45 m were prepared in a staggered manner of an aligned contour at a vertical interval of 1 m. Two rows of *Stylosanthes scabra* followed by one row of *Vetiveria zizanioides* at a spacing of 50 cm were planted as vegetative barriers on the downstream side of the trench bund.
T_5- Semi elliptical trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* (SET + VB)	The trenches 2 m length, top width 0.45m, bottom width 0.30 and depth of 0.45 m, were prepared in respect to each plant in a semi elliptical manner on the upstream side of the plant. Two rows of *Stylosanthes scabra* followed by one row of *Vetiveria zizanioides* at a spacing of 50 cm were planted as vegetative barriers on the downstream side of the trench bund.
T_6 - Control	Without any soil and water conservation measure

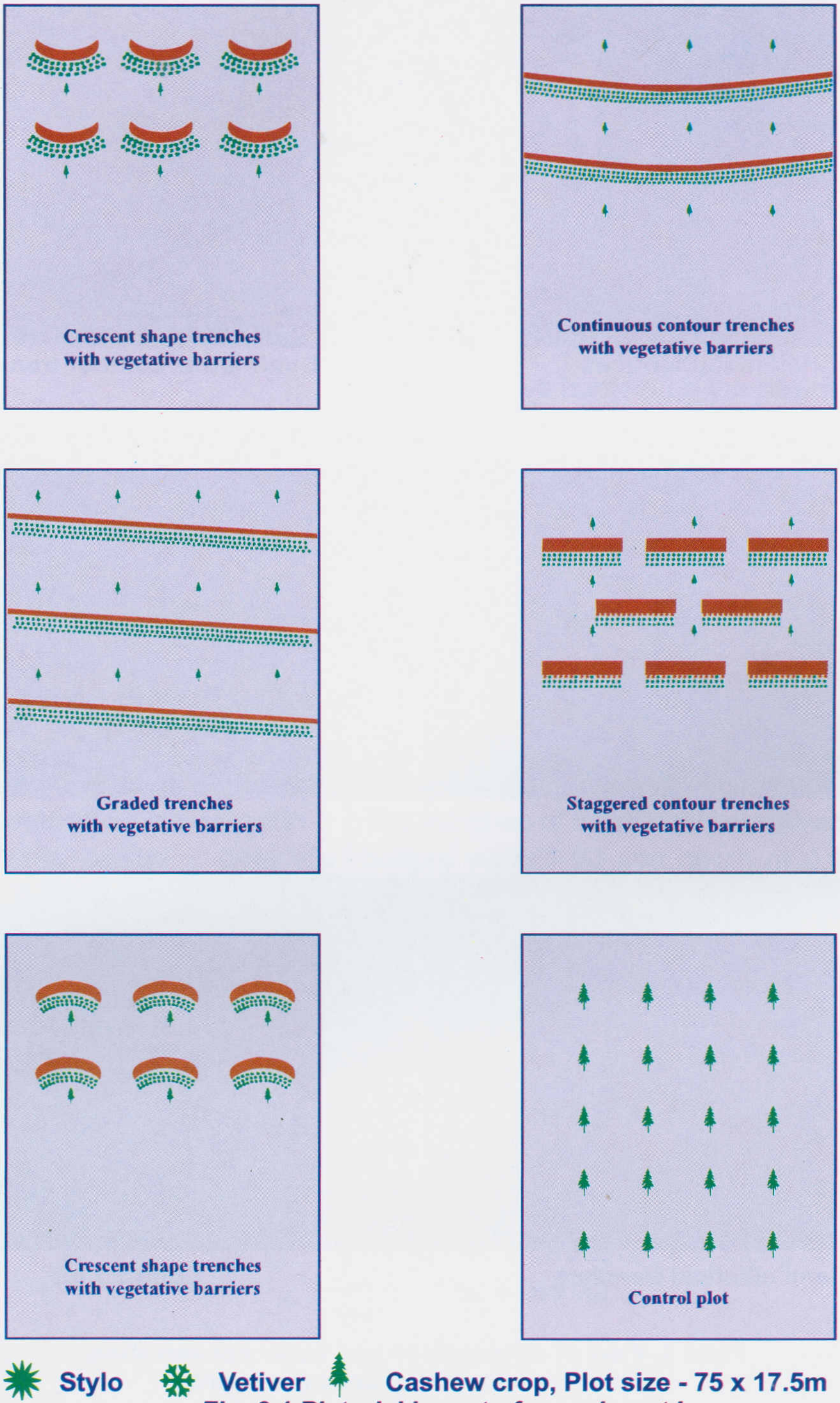


Fig. 3.1 Pictorial layout of experiment I

Half moon terraces

Continuous contour trenches

Graded trenches

Staggered contour trenches

Semi elliptical trenches

Control plot

Plate 1. View of different soil and water conservation measures imposed under experiment I

Table 3.2. Treatment details and specifications of *in-situ* moisture conservation measures adapted for cashew at 6 m X 6 m spacing

Treatments	Specification
T_1 – Continuous Contour Trench + *Stylosanthes scabra* + *Gliricidia maculate* (CCT + VB)	The trenches for field length with top width of 0.45 m, bottom width of 0.30 m and depth of 0.45 m were made continuously along the contour having the vertical interval of 1 m. Two rows of *Stylosanthes scabra* followed by one row of *Gliricidia maculata* at a spacing of 50 cm were planted as live barriers on the downstream side of the trench bund.
T_2 – Staggered Contour Trench + *Stylosanthes scabra* + *Gliricidia maculate* (SCT + VB)	The trenches of length of 2m, top width 0.45 m, bottom width 0.30 and depth of 0.45 m were prepared in a staggered manner of an aligned contour. Two rows of *Stylosanthes scabra* followed by one row of *Gliricidia maculata* at a spacing of 50 cm were planted as live barriers on the down stream side of the trench bund.
T_3 – Crescent Shape Trench + *Stylosanthes scabra* + *Gliricidia maculata* (CST + VB)	The trenches of length of 2m, top width 0.45 m, bottom width 0.30 and depth of 0.45 m were prepared in case of each plant in a crescent shape on the up stream side of the plant. Two rows of *Stylosanthes scabra* followed by one row of *Glyricidia maculata* at a spacing of 50 cm were planted as live barriers on the down stream side of the trench bund.
T_4 - *Stylosanthes scabra* + *Gliricidia maculata* alone (VB)	Two rows of *Stylosanthes scabra* followed by one row of *Gliricidia maculata* at a spacing of 50 cm were planted as live barriers along the contour at 1 m vertical interval.
T_5 – Control	Without any soil and water conservation measure

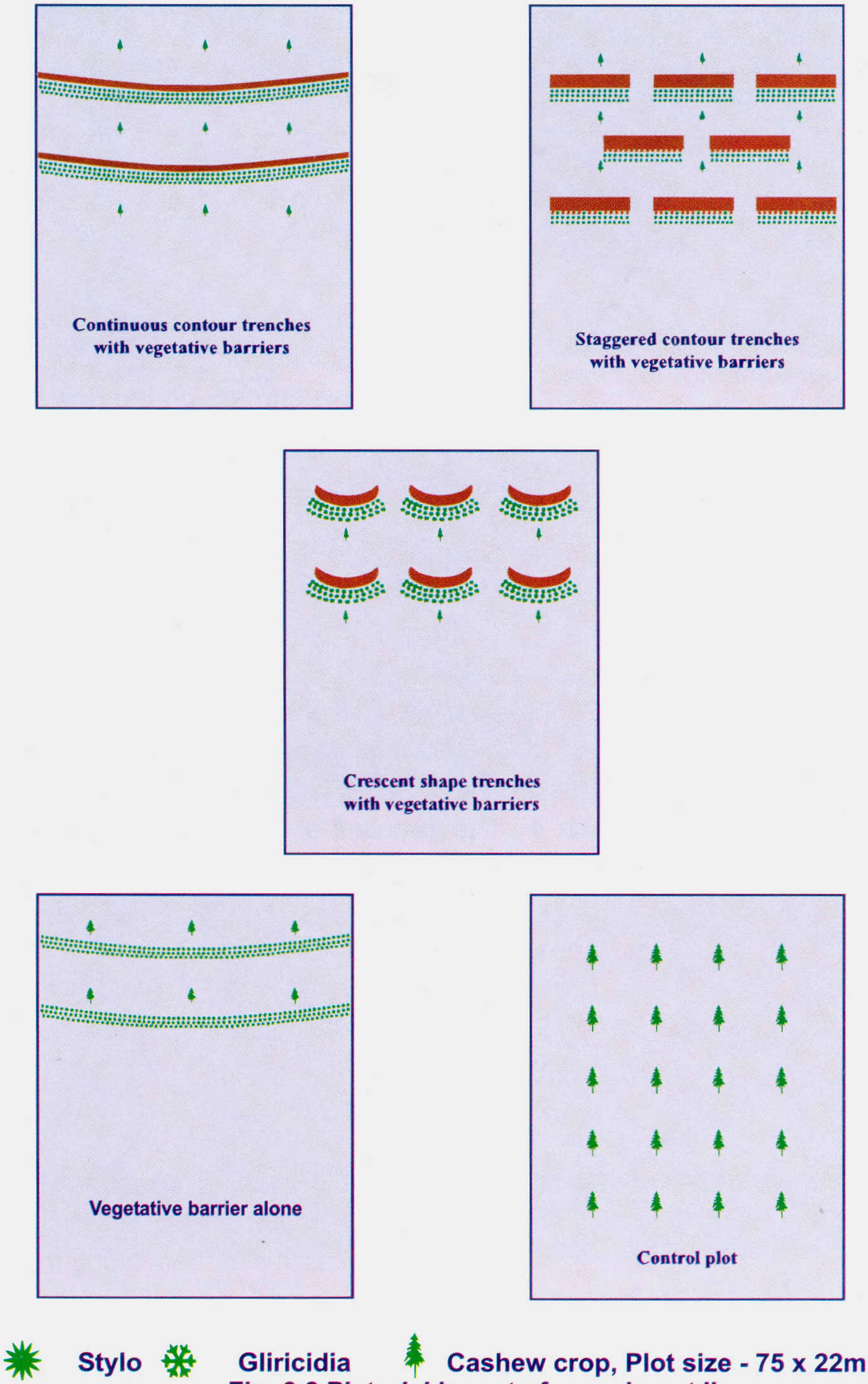


Fig. 3.2 Pictorial layout of experiment II

3.2. Experimental design

Randomized block design with three replications was adopted in this study. However, for monitoring hydrological parameters, time replication was followed for five years period from 2002 to 2006.

3.3. Cultivation practices

Normal recommended cultivation practices including plant protection measures were adopted uniformly in all the treatments. Fertilizer was applied uniformly to all the treatments as furnished in Table 3.3.

3.4. Measurement of runoff

Rainfall and runoff were continuously monitored for five years period from 2002 to 2006 in both the experiments.

3.4.1. Experiment I

At the down stream outlet of each experimental plot, 60 cm H-Flume structure was constructed. Daily runoff was determined from the runoff hydrograph recorded by the automatic water stage level recorder installed on stilling wells which were constructed near the 60 cm H Flume structure. The rise of water in the stilling well is proportionately transmitted to the drum with the help of float, counter weight, float pulley and the float cable. A pen fitted near the drum moves at a uniform speed along the horizontal axis whereas the drum moves in the vertical axis. A chart is affixed in the drum. The relative movements of the charts and the pen produce a curve called stage-graph, which was analyzed to determine the amount of runoff. Weekly, monthly and annual runoff was calculated from the daily runoff.

3.4.2. Experiment II

The runoff in second experiment was regularly measured by a series of multi-slot devisors. Daily runoff was measured in runoff tanks and weekly, monthly and annual runoff was calculated from the daily runoff.

3.5. Determination of soil and nutrient losses

In first experiment, N-2 model Coshocton wheel sampler was locally fabricated and installed at the outlet of

Table 3.3. Fertilizer doses applied for cashew (kg tree $^{-1}$)

Age of tree (yr)	N (g)	P_2O_5 (g)	K_2O (g)	Urea (kg)	Mussorie Rock Phosphate(kg)	Muriate of Potash (kg)
1	100	80	—	0.2	0.4	—
2	200	80	60	0.4	0.4	0.10
3	400	120	120	0.8	0.6	0.20
4 and above	500	125	125	1.0	0.7	0.25

H flume in all the experimental plots. The discharge from the measuring H flume falls upon a water wheel, whose axis is inclined slightly from vertical. A sampling head, with a narrow opening along its top called as slot was mounted on the wheel. With each revolution of the wheel, the slot cuts across the water jet from the flume and extract a small portion of the flow. The extracted portion or sample splashes through and moves inside of the sampling head, the wheel plates into a collecting pan beneath the wheel. From there, the sample was collected through a suitable closed conduit to a sample storage tank.

After every rainfall event at 8.30 A.M. (IST), the runoff collected in silt collecting tanks was thoroughly mixed and immediately a representative sample was drawn in bottles of 1000 ml capacity. Runoff so collected in sample bottle was taken and the silt was allowed to settle down. After draining the excess water, the soil was kept in the hot air oven and dry weight was recorded. The soil loss was estimated in proportion with total runoff occurred in particular rainfall event. From the individual event, the annual soil loss was worked out and converted to unit area.

In case of second set of experiment, the total runoff collected per day in all the runoff tanks of multi slot devisors in each experimental plot was thoroughly mixed and a one litre runoff sample was taken for determination of soil loss.

Similarly, another representative sample was collected in 1000 ml bottle and used to estimate the nutrients losses. Major nutrient losses namely N, P and K were estimated under various conservation measures by using the routine nutrient analytical procedures.

3.6. Soil, water and soil & water conservation efficiencies

Water Conservation Efficiency (WCE) and Soil Conservation Efficiency (SCE) of different conservation measures in comparison to control were calculated in per cent as given below:

$$\text{WCE or SCE} = \left[\frac{(A-B)}{A}\right] * 100 \qquad (3.6.1)$$

Where,

A - Runoff or soil loss from control plot

B - Runoff or soil loss from conservation measures

From WCE and SCE, Soil & Water Conservation Efficiency (SWCE) in per cent was calculated as below by assigning equal weightage to both water and soil conservation efficiency.

$$\text{SWCE} = \frac{[\text{WCE}+\text{SCE}]}{2} \qquad (3.6.2)$$

3.7. Soil moisture content

Soil moisture content was

monitored at 0-30 cm, 30-60 cm and 60-90 cm depths after the monsoon at regular intervals to quantify the effect of bio-engineering measures on moisture retaining capacity of soil. In this study, soil moisture content was measured gravimetrically during the first fortnight of November, January, March and May months for five years period (From 2002-03 to 2006-07).

3.8. Status of major nutrients

Major nutrients *viz.* organic carbon, available nitrogen, phosphorus and potassium at every two years interval i.e., 2002, 2004 and 2006 in all the treatments were monitored. The nutrient contents were estimated up to the depth of 90 cm at 30 cm depth interval. Standard procedures were followed to analyze the nutrients.

3.9. Growth parameters and yield of cashew

Growth parameters of cashew crop namely, height, girth, primary and secondary branches were recorded at an interval of 12 months till 60 months after the date of plantation. In case of second experiment, the growth parameters were recorded at an interval 12 months till 36 months after the date of plantation. Cashew yield was recorded for the crop years 2004-05, 2005-06 and 2006-07 (fourth, fifth and sixth year of after plantation). Average nut yield per tree and total yield of cashew nut were recorded.

3.10. Economic analysis

Economic measures such as net present worth (NPW) benefit-cost ratio (BCR) and internal rate of return (IRR) were worked out to assess the economic impact of different soil and water conservation measures.

3.10.1. Net present worth

NPW is the present worth of the incremental net benefit or incremental cash flow stream. It was computed by finding the difference between the present worth of the benefit stream less the present worth of the cost stream.

$$NPW = \sum_{i=1}^{n} \frac{B_n}{(1+i)^n} - \sum_{i=1}^{n} \frac{C_n}{(1+i)^n} \quad (3.10.1)$$

where,

B_n - Benefits in the period 'n'

C_n - Cost in the period 'n'

i - Discount rate

n - Number of years

In benefit stream, yield of cashew nuts, apple and vegetative barriers were taken into account. Cost of cultivation and soil and water conservation measures were taken in to account while calculating the cost stream. Economic life of soil and water conservation measures was assumed as 10 years.

3.10.2. Benefit - cost ratio

Benefit -cost ratio was obtained by dividing the worth of the benefit stream by worth of the cost stream.

$$NPW = \sum_{i=1}^{n} \frac{B_n/(1+i)^n}{Cn_n/(1+i)^n} \qquad (3.10.2)$$

3.10.3. Internal rate of return

IRR is the rate that makes the net present worth of the incremental net benefit stream or incremental cash flow equal to zero.

$$\sum_{i=1}^{n} \frac{B_n}{(1+i)^n} - \sum_{i=1}^{n} \frac{B_n}{(1+i)^n} = 0 \qquad (3.10.3)$$

It is the maximum interest rate that the conservation measures could pay for the resources used if its investments and operating costs are to be recovered. IRR was calculated by using the approximation method.

3.11. Statistical analysis

The growth parameters and yield were statistically analyzed by using analysis of variance. In the present study, data were tested to assess the existence of significant differences between the treatments. The consistency of the treatment responses at different years was also tested.

4. RESULTS AND DISCUSSION

The quantitative impacts of different soil and water conservation measures on runoff, soil and nutrient loss, soil moisture content, major nutrient status and growth parameters, yield and economic feasibility of different conservation measures for cashew are reported and discussed.

4. 1. Experiment 1

4.1.1. Annual runoff

The annual rainfall received and the observed runoff values for the study period are given in Table 4.1. The annual rainfall received during the year 2002 (2312.5 mm) and 2004 (2432.9 mm) were lesser than the rainfall of 2003 (3124.2 mm), 2005 (3269.1 mm) and 2006 (3217.0 mm). In general, the runoff was less in all the treatments due to porous nature of lateritic soils in all the years. But, the annual runoff in the years 2002 and 2004 was still less compared to other years due to lesser rainfall amount with less intensity of rainfall and occurrence of frequent dry spells during the years 2002 and 2004. Even though the high rainfall of 3124.2 mm was received during the year 2003, the runoff was less due to the uneven distribution of rainfall, which resulted in frequent dry spells that did not produce the expected runoff. A minimum runoff of 74.4 mm, 121.5 mm, 275 mm, 719.1 mm and 641.9 mm, respectively was observed during the years 2002, 2003, 2004, 2005 and 2006 under the treatment of continuous contour trenches with *S. scabra* and *V. zizanioides.* This was followed by 89.7 mm (2002), 168.9 mm (2003), 333.6 mm (2004), 803.4 mm (2005) and 769.4 mm (2006) runoff under the treatment comprising of staggered contour trenches with *S. scabra* and *Vetivaria zizanoides* as against maximum

Table 4.1 Effect of bio-engineering measures in controlling annual runoff

Year	Rainfall (mm)	Runoff (mm)					
		HMT + VB	CCT + VB	GT + VB	SCT + VB	SET + VB	Control
2002	2312.5	94.1	74.4	93.2	89.7	99.6	192.7
2003	3124.2	193.2	121.5	231.0	168.9	185.1	272.3
2004	2432.9	432.0	275.0	388.2	333.6	377.7	503.0
2005	3269.1	997.2	719.1	912.2	803.4	849.3	1195.1
2006	3217.0	1025.9	641.9	933.6	769.4	836.2	1159.6
Mean	**2871.1**	**548.5**	**366.4**	**511.6**	**433.0**	**469.6**	**664.5**

runoff of 192.7 mm (2002), 272.3 mm (2003), 503 mm (2004), 1195.1 mm (2005) and 1159.6 mm (2006) recorded in control plot where there was no imposition of conservation treatment.

The mean runoff data show that all the bio-engineering measures reduced the amount of runoff in all the years as compared to the control plot. Maximum reduction of 298.1 mm was observed in continuous contour trenches with *S. scabra* and *V. zizanioides* followed by 231.5 mm, 194.9 mm, 152.9 mm and 116.0 mm in staggered contour trenches with *S. scabra* and *V. zizanioides*, semi elliptical trenches with *S. scabra* and *V. zizanioides*, graded trenches with *S. scabra* and *V. zizanioides* and half moon terraces with *S. scabra* and *V. zizanioides*, respectively.

The percentage of runoff to rainfall was worked out and is furnished in Table 4.2. In general, all the treatments produced less runoff. The runoff varied from 3.2 to 31.9 per cent of the annual rainfall under different conservation treatments against the maximum runoff of 8.3 and 36.6 per cent of annual rainfall in control plot. High infiltration rate (12 to 17 cm hr^{-1}) due to porous soil could be one of the main factors of reducing the percentage of runoff in all the treatments. However, the percentage of runoff was comparatively less during the year 2002 (From 3.2 % to 8.3 %) and 2003 (From 3.9 % to 8.7 %) due to the disturbed nature of soil on account of the tillage operations for initial establishment.

Continuous contour trenches with *S. scabra* and *V. zizanioides* as vegetative barriers produced 12.8 per cent of runoff to annual rainfall showed a reduction of runoff to 44.5 per cent over the control plot followed by 34.6 per cent in staggered contour trenches with *S. scabra* and *V. zizanioides* against the minimum runoff

Table 4.2. Percentage of runoff to rainfall under different conservation measures

Year	Percentage of runoff to rainfall (per cent)					
	HMT + VB	CCT + VB	GT + VB	SCT + VB	SET + VB	Control
2002	4.1	3.2	4.0	3.9	4.3	8.3
2003	6.2	3.9	7.4	5.4	5.9	8.7
2004	17.8	11.3	16.0	13.7	15.5	20.7
2005	30.5	22.0	27.9	24.6	26.0	36.6
2006	31.9	20.0	29.0	23.9	26.0	36.0
Mean	**18.1**	**12.8**	**17.8**	**15.1**	**16.4**	**23.1**

reduction of 21.6 per cent in half moon terraces with *S. scabra* and *V. zizanioides.* The conservation measures *viz.*, semi elliptical trenches with *S. scabra* and *V. zizanioides* and graded trenches with S. scabra and V. zizanioides also reduced the runoff percentage (29.0 % and 23.0 %, respectively) over the control plot. This reduction in runoff under different bio-engineering measures was attributable to their effect, which reduces runoff velocity and increases infiltration opportunity time for water.

The results reveal that all the bio-engineering measures in cashew plantation on hill slope had a significant effect on reducing the runoff. The bio-engineering measures reduced the runoff by 6.7 to 10.3 per cent as compared to no treatment. Out of five bio-engineering measures, continuous contour trenches with *S. scabra* and *V. zizanioides* and staggered contour trenches with *S. scabra* and *V. zizanioides* reduced the runoff by 44.5 and 34.6 per cent, respectively.

4.1.2. Impact on annual soil loss

The annual soil loss was measured for the study period and the same is presented in Table 4.3. The soil loss was higher in all the treatments during the year 2002 as compared to the years 2003, 2004, 2005 and 2006. This might be due to the fact that it was the second year of plantation and the tillage operations resulted in disturbance of top soil and led to higher soil loss in the initial years which was reduced in subsequent years due to adequate build up of cashew canopy. The treatment continuous contour trenches with *S. scabra* and *V. zizanioides* showed the lowest level of average soil loss of 12.3 t ha^{-1} yr^{-1}. Staggered contour trenches with *S. scabra* and *V. zizanioides,* semi elliptical trenches with *S. scabra* and *V. zizanioides,* graded trenches with *S. scabra* and *V. zizanioides* and half moon terraces with *S. scabra* and *V. zizanoides* resulted in the soil loss of 15.5, 17.1, 18.3 and 19.2 t ha^{-1} yr^{-1}, respectively. The maximum average soil loss of 23.6 t ha^{-1} yr^{-1} was recorded in control treatment where there was no conservation measure.

Minimum soil loss of 6.1 t ha^{-1} was observed in the treatment of continuous contour trenches with *S. scabra* and *V. zizanioides* and was followed by 9.0 t ha^{-1} in staggered contour trenches with *S. scabra* and *V. zizanioides.* Maximum soil loss of 18.5 t ha^{-1} was observed in control plot during the year 2006. Continuous contour trenches with *S. scabra* and *V. zizanioides* and staggered contour trenches with *S. scabra* and *V. zizanioides* reduced the soil loss by 11.3 and 8.1 t ha^{-1} yr^{-1} in cashew field when compared with control.

Table 4.3. Annual soil loss as influenced by different bio-engineering measures

Year	Soil loss ($t\ ha^{-1}\ yr^{-1}$)					
	HMT + VB	CCT + VB	GT + VB	SCT + VB	SET + VB	Control
2002	26.8	19.3	25.1	22.9	24.3	29.8
2003	23.2	16.4	21.2	18.1	19.6	26.1
2004	18.1	11.5	17.5	14.8	16.7	22.4
2005	15.7	8.4	15.1	12.6	14.5	21.2
2006	12.4	6.1	12.5	9.0	10.2	18.5
Mean	**19.2**	**12.3**	**18.3**	**15.5**	**17.1**	**23.6**

Thus, it is inferred that continuous contour trenches with *S. scabra* and *V. zizanioides* as vegetative barrier were the best when compared to all other treatments for soil loss reduction. Staggered contour trenches with *S. scabra* and *V. zizanioides* was found as the next best treatment in reducing the soil loss.

4.1.3. Nutrient losses

The losses of major nutrients (N, P and K) were estimated annually for five years and the same is furnished in Table 4.4. The data show that all the bio-engineering measures reduced the nutrient losses in all five years as compared to control plot. In general, the nutrient losses were directly proportional to the soil loss in all the treatments. The mean values indicate that minimum nitrogen loss was 16.2 kg ha^{-1} in the treatment of continuous contour trenches with *S. scabra* and *V. zizanioides* followed by 18.0 kg ha^{-1} in the treatment comprising staggered contour trenches with *S. scabra* and *V. zizanioides* while the maximum nitrogen loss of 35.8 kg ha^{-1} was recorded in control plot. Similarly, the potassium loss was minimum (19.2 kg ha^{-1}) in the treatment continuous contour trenches with *S. scabra* and *V. zizanioides* followed by 28.1 kg ha^{-1} loss in the treatment staggered contour trenches with *S. scabra* and *V. zizanioides* as against the maximum potassium loss of 58.8 kg ha^{-1} observed in control plot. The lowest loss of potassium through staggered trenches under cashew land use was reported earlier in similar type of soil (Badhe and Magar, 2004). The phosphorus losses ranged from 0.5 to 1.2 kg ha^{-1} in the plots where conservation practices were adopted as compared to 1.9 kg ha^{-1} in the plots where there was no conservation measure. Negligible amount of phosphorus loss was due to the nature of the phosphorus, which does not move as fast as other nutrients in the runoff and being acidic in nature phosphorous fixing capacity of the soil is very high.

Table 4.4. Nutrient losses in the cashew fields under various bio-engineering measures (kg ha^{-1})

Treatment	2002			2003			2004			2005			2006			Mean		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
HMT + *VB*	21.9	1.8	48.9	21.7	0.4	38.9	18.8	0.6	23.8	17.9	1.8	25.3	17.0	1.2	24.0	19.5	1.2	32.2
CCT + VB	18.1	0.5	28.5	17.5	0.1	17.5	15.8	0.1	16.5	14.6	0.5	16.5	15.0	0.4	17.0	16.2	0.3	19.2
GT + VB	22.6	2.0	51.4	21.1	0.4	41.4	18.9	0.2	28.3	17.8	2.0	27.8	18.2	1.5	28.0	19.7	1.2	35.4
SCT + VB	19.9	0.8	35.9	19.9	0.1	18.9	16.9	0.1	14.8	17.2	0.8	35.9	16.0	0.7	35.0	18.0	0.5	28.1
SET + VB	20.3	1.4	40.8	20.5	0.1	20.7	17.3	0.1	16.5	17.5	1.4	40.8	18.0	0.9	35.0	18.7	0.8	30.8
Control	47.3	2.6	67.2	43.6	1.6	65.1	30.6	1.0	44.2	28.9	2.6	42.6	28.6	1.8	40.8	35.8	1.9	52.0

4.1.4. Soil, water and soil & water conservation efficiencies

Soil conservation efficiency, water conservation efficiency and soil and water conservation efficiency were worked out for each year and the values are furnished in Table 4.5. The highest water conservation efficiency (WCE) of 61.4, 55.4, 45.3, 39.8 and 44.6 per cent were recorded in continuous contour trenches with *S. scabra* and *V. zizanioides* during the years 2002, 2003, 2004, 2005 and 2006, respectively. The mean values of water conservation efficiency of continuous contour trenches with *S. scabra* and *V. zizanioides,* staggered contour trenches with *S. scabra* and *V. zizanioides,* Semi elliptical trenches with *S. scabra* and *V. zizanioides* were 49.3, 38.3 and 32.4 %, respectively.

The average SCE of continuous contour trenches with *S. scabra* and *V. zizanioides,* staggered contour trenches with *S. scabra* and *V. zizanioides*, semi elliptical trenches with *S. scabra* and *V. zizanioides*, graded trenches with *S. scabra* and *V. zizanioides* and half moon terraces with *S. scabra* and *V. zizanioides* were 49.7, 35.9, 29.1, 23.5 and 19.9 %, respectively. Overall, the highest soil and water conservation efficiency was observed in continuous contour trenches with *S. scabra* and *V. zizanioides* (49.5%) followed by staggered contour trenches with *S. scabra* and *V. zizanioides* (37.1 %) and it was the lowest (22.2 %) in half moon terraces with *S. scabra* and *V. zizanioides.*

4.1.5. Impact on soil moisture content

The soil moisture content at 30, 60 and 90 cm depths were monitored at periodical intervals after cessation of monsoon and the mean data for five years are furnished in Table 4.6. It was observed that the soil moisture content at 30 cm soil depth varied from 24.0 to 27.4 per cent under different bio-engineering measures during November against the moisture content of 21.7 per cent recorded in control plot. Similarly, the soil moisture content at 60 and 90 cm soil depths ranged from 24.5 to 28.1 per cent and from 24.8 to 28.5 per cent under different bio-engineering measures during November. A similar trend in soil moisture was continued till the month of May.

The maximum soil moisture content (13.3 per cent) at 30 cm soil depth was recorded under continuous contour trenches with *S. scabra* and *V. zizanioides* followed by staggered contour trenches with *S. scabra* and *V. zizanioides* (12.3 %) against the least soil moisture content (9.1 per cent) observed in control plot during May. Similar trend was observed at 60 and 90 cm soil depths. It could be inferred clearly from the values of soil moisture content at different soil depths that the bio-engineering measures increase

Table 4.5. Water, soil and soil and water conservation efficiencies of different bioengineering measures

Year	Treatment				
	HMT +VB	CCT +VB	GT + VB	SCT + VB	SET + VB
			Water conservation efficiency (%)		
2002	51.2	61.4	51.6	53.5	48.3
2003	29.0	55.4	15.2	38.0	32.0
2004	14.1	45.3	22.8	33.7	24.9
2005	16.6	39.8	23.7	32.8	28.9
2006	11.5	44.6	19.5	33.6	27.9
Mean	**24.5**	**49.3**	**26.6**	**38.3**	**32.4**
			Soil conservation efficiency (%)		
2002	10.1	35.2	15.8	23.2	18.5
2003	11.1	37.2	18.8	30.7	24.9
2004	19.2	48.7	21.9	33.9	25.4
2005	25.9	60.4	28.8	40.6	31.6
2006	33.0	67.0	32.4	51.4	44.9
Mean	**19.9**	**49.7**	**23.5**	**35.9**	**29.1**
			Soil and water conservation efficiency (%)		
2002	30.6	48.3	33.7	38.3	33.4
2003	20.1	46.3	17.0	34.3	28.5
2004	16.7	47.0	22.3	33.8	25.2
2005	21.3	50.1	26.2	36.7	30.3
2006	22.3	55.8	26.0	42.5	36.4
Mean	**22.2**	**49.5**	**25.0**	**37.1**	**30.7**

Table 4.6. Effect of bio-engineering measures on soil moisture content at different soil depths

Treatment	Soil depth (cm)	Soil moisture content (per cent)			
		November	January	March	May
HMT + VB	0-30	24.0	17.3	13.2	10.1
	30-60	24.5	17.6	14.0	10.8
	60-90	24.8	18.3	14.4	11.2
CCT + VB	0-30	27.4	21.2	17.2	13.3
	30-60	28.1	21.8	17.8	14.0
	60-90	28.5	22.6	18.2	14.7
GT + VB	0-30	24.7	17.3	13.9	10.8
	30-60	25.3	18.1	14.6	11.6
	60-90	25.8	18.9	14.8	12.2
SCT + VB	0-30	26.1	19.3	15.9	12.3
	30-60	27.1	20.3	16.5	12.7
	60-90	27.5	20.7	17.0	13.2
SET + VB	0-30	25.2	18.4	14.8	11.1
	30-60	25.9	19.2	15.4	11.7
	60-90	26.2	19.6	15.8	12.1
Control plot	0-30	21.7	16.4	12.1	9.1
	30-60	22.2	16.9	12.9	9.7
	60-90	22.7	17.5	13.2	10.4

the soil moisture content and retain the soil moisture till May. This can be attributed obviously to less runoff and adequate intake of water in the soil profile. Further, the results reveals that the continuous contour trenches with *S. scabra* and *V. zizanioides* was found to be the ideal and suitable conservation measure to retain soil moisture for longer duration after cessation of monsoon. Alternatively, the staggered contour trenches with *S. scabra* and *V. zizanioides* were found to be efficient in retaining soil moisture.

4.1.6. Effect on major nutrient status

The data recorded on soil fertility build up during the years from 2002 to 2006 at three soil depths (30, 60 and 90 cm) are presented in Table 4.7. In general, decreasing trend of organic carbon and available nitrogen, phosphorus and potassium was observed from the year 2002 to 2006 in all the treatments. However, there were significant differences in the rate of decrease among the treatments over years. For example, the organic carbon content at 30 cm depth in the continuous contour trenches with *S. scabra* and *V. zizanioides* treatment was 1.16 per cent in the year 2002 and the same was reduced to 1.00 per cent in 2004 and stabilized at same level during the year 2006. The organic carbon content at 60 and 90 cm soil depths under all treatments also showed similar trend. The decreasing rates of organic carbon content over the periods were high in the field where there were no conservation measures adopted. Similar trend was observed in case of available nitrogen, phosphorus and potassium under different conservation measures.

The available nitrogen was high up to a depth of 30 cm and decreased gradually at 60 and 90 cm depths. Similar trend was observed in case of available phosphorus and potassium. There was no significant difference in the status of major nutrients among the treatments over the four years. The data on nutrient status over four year periods show that there was not much difference in treated fields and untreated one during the year 2002. However, there was a visible difference in the nutrient status of treated cropland by conservation measures as compared to untreated field during the years 2004 and 2006. For example, the available phosphorus at 30 cm soil depth under continuous contour trenches with vegetative barriers was 14.7 kg ha^{-1} whereas 8.0 kg ha^{-1} was recorded in control plot during the year 2006. The available potassium at 30 cm depth under continuous contour trenches with vegetative barriers was 202.8 kg ha^{-1} as compared to 134.4 kg ha^{-1} in control plot during the year 2006.

It could be inferred that the bio-engineering measures contributed to

Table 4.7. Nutrients status of soil as affected by different bio-engineering measures

Treatment	Soil Depth (cm)	Organic carbon (per cent)			N (kg ha^{-1})			P (kg ha^{-1})			K (kg ha^{-1})		
		2002	*2004*	*2006*	*2002*	*2004*	*2006*	*2002*	*2004*	*2006*	*2002*	*2004*	*2006*
HMT + VB	0-30	1.13	0.90	0.89	118.0	110.6	102.6	13.1	11.5	9.8	238.9	224.0	232.8
	30-60	0.81	0.78	0.68	70.4	74.6	70.0	12.3	10.6	9.8	164.3	170.1	168.9
	60-90	0.80	0.79	0.67	44.3	48.6	43.5	11.1	9.8	8.5	123.1	126.5	125.2
CCT + VB	0-30	1.16	1.00	1.05	114.6	108.5	110.0	14.7	13.9	14.7	201.6	213.6	202.8
	30-60	0.87	0.79	0.75	75.0	71.9	73.6	11.4	12.5	11.9	171.7	168.9	165.4
	60-90	0.84	0.75	0.75	40.4	45.6	48.6	9.3	9.0	9.8	142.1	141.3	144.2
GT + VB	0-30	1.16	0.95	0.67	100.2	92.0	90.6	14.7	11.6	9.0	201.6	212.5	246.5
	30-60	1.11	0.88	0.64	96.2	90.5	89.6	14.7	10.6	8.0	164.3	158.9	163.5
	60-90	0.70	0.65	0.65	45.6	46.0	44.0	10.6	9.4	8.0	149.0	152.9	145.6
SCT + VB	0-30	1.07	1.00	0.90	102.4	90.5	96.8	14.7	14.9	14.7	226.9	224.6	212.8
	30-60	0.75	0.70	0.70	86.0	81.6	49.8	11.3	9.8	10.5	141.9	159.2	143.7
	60-90	0.68	0.67	0.64	38.5	34.5	40.9	13.2	9.5	9.0	113.6	125.6	128.0
SET + VB	0-30	1.11	1.02	0.92	104.8	108.1	101.6	11.4	9.8	8.8	249.3	241.2	201.2
	30-60	0.89	0.82	0.78	76.7	82.3	75.6	8.5	4.9	5.0	159.8	165.3	162.5
	60-90	0.85	0.82	0.69	48.2	52.6	50.6	8.6	4.8	4.9	132.6	140.3	138.9
Control	0-30	0.99	1.05	0.67	105.9	90.5	94.9	11.4	10.5	8.0	238.9	200.1	134.4
	30-60	0.94	0.78	0.65	81.3	80.6	74.1	8.4	7.6	8.2	141.8	135.6	130.5
	60-90	0.85	0.48	0.65	46.6	45.0	41.0	8.4	4.9	4.5	109.4	101.5	104.3

maintain the nutrient levels after third year of planting. This might be due to the fact that the conservation measures reduced the nutrient losses from the treated plots as compared to control plot. However, the fertility status needs to be monitored for longer periods to find the consistent effect of soil and water conservation measures.

4.1.7. Growth parameters of cashew

The survival percent of cashew grafts under different conservation measures are depicted in Fig. 4.1. Maximum survival of 94 per cent was recorded under continuous contour trenches with *S. scabra* and *V. zizanioides* treatment followed by 90 per cent under SCT with *S. scabra* and *V. zizanioides* and SET with *S. scabra* and *V. zizanioides.* Least survival of 52 per cent was observed in control plot.

The growth parameters *viz.*, height, girth, primary and secondary branches under different treatments were recorded at 12 months interval till 60 months after the date of plantation and same is depicted in Figures 4.2 and 4.3. In general, cashew growth under different bio-engineering measures was better as compared to control plot. There was significant difference in growth parameters of cashew plants after twelve months of planting among the treatments.

Maximum height of cashew (619.4 cm) was recorded in continuous contour trenches with *S. scabra* and *V. zizanioides* treatment followed by 593.4 cm in SCT with *S. scabra* and *V. zizanioides* treatment after 60 months of planting. This was followed by 583.3 cm, 573.3 cm and 540.7 cm in treatments comprising of SET with *S. scabra* and *V. zizanioides,* GT with *S. scabra* and *V. zizanioides* and HMT with *S. scabra* and *V. zizanioides,* respectively. The lowest height of 435.4 cm was recorded in cashew plants planted in control plot (Fig. 4.2). The increase in height of cashew plants was maximum (184 cm) in treatment comprising of continuous contour trenches with vegetative barriers followed by staggered contour trenches with vegetative barriers (158 cm).

Maximum girth of cashew plant (54.9 cm) was recorded in continuous contour trenches with *S. scabra* and *V. zizanioides* treatment followed by 50.6 cm in treatment comprising of SCT with *S. scabra* and *V. zizanioides* after 60 months of planting. This was followed by 48.6, 46.0 and 44.3 cm in treatments comprising of SET with *S. scabra* and *V. zizanioides*, GT with *S. scabra* and *V. zizanioides* and HMT with *S. scabra* and *V. zizanioides*, respectively. The lowest girth of 40.7 cm was recorded in cashew plants in control plot (Fig. 4.2). Maximum increase in girth (14.2 cm) was observed in treatment comprising of continuous contour trenches with live vegetative barriers followed

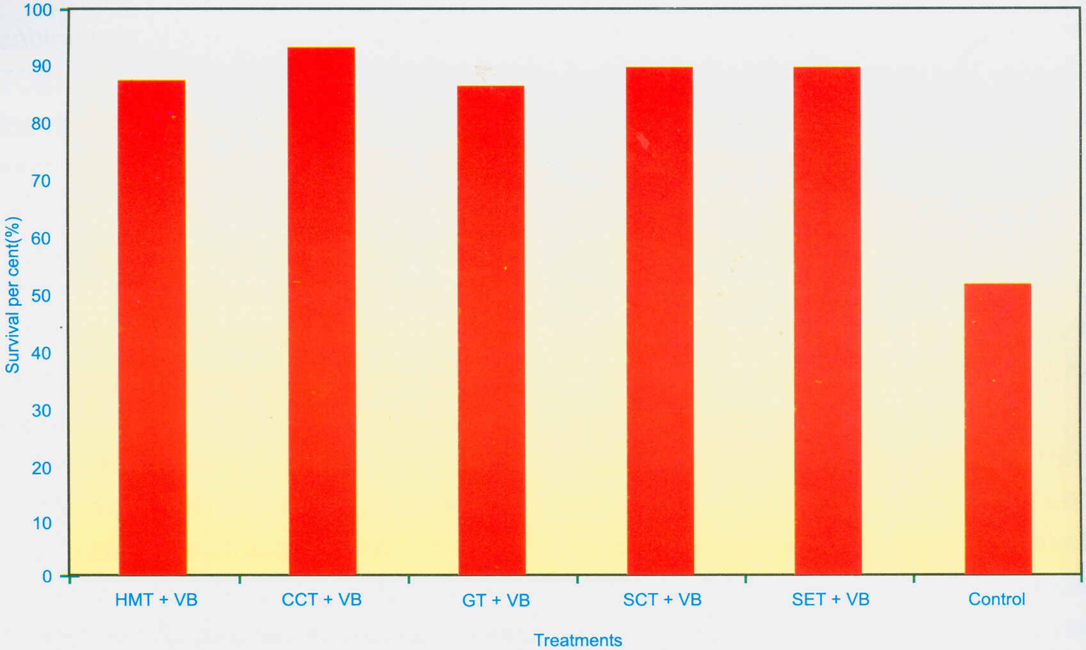


Fig. 4.1 Survival percentage of cashew plants under different conservation measures

Plate 2. Establishment of stylo and vetiver at d/s of CCT

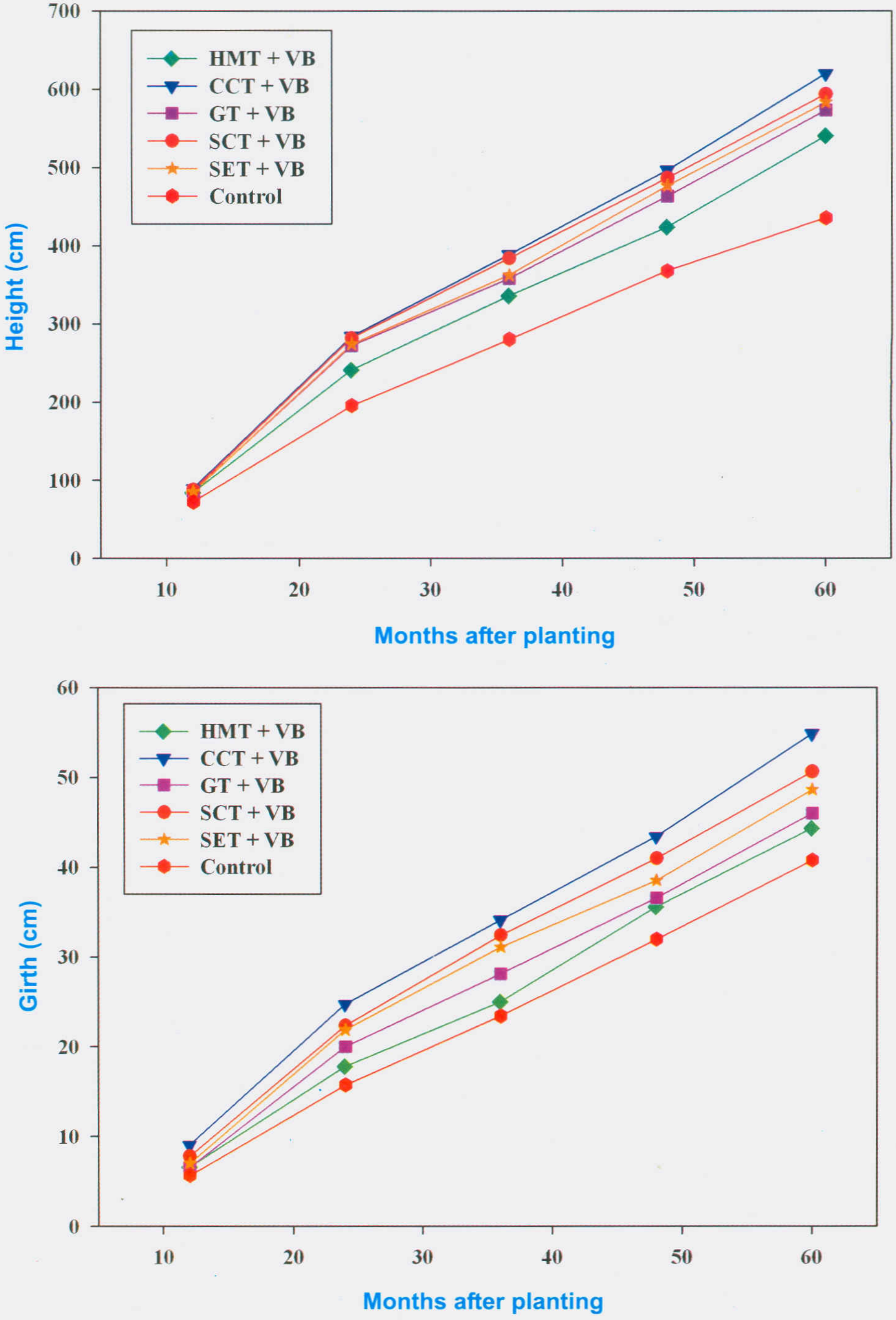


Fig. 4.2. Effect of bioengineering measures on height and girth of the cashew at different growth stages

The maximum number of primary and secondary branches (38 and 90 / plant, respectively) were observed in CCT with vegetative barrier (Fig. 4.3) and were followed by SCT with vegetative barrier (35 primary branches and 87 secondary branches / plant) after 60 months of planting. The increase in branching habit of cashew plants was also maximum in CCT with vegetative barriers (10 primary branches and 20 secondary branches / plant) followed by SCT with vegetative barriers (7 primary branches and 17 secondary branches / plant).

Thus, the bio-engineering measures helped in improving better growth parameters of cashew. It is pertinent to note that growth performance of cashew was found better under continuous contour trenches and staggered contour trenches with vegetative barriers among the bio-engineering measures.

Plate 3. Six years old cashew crop under CCT.

Plate 4. Six years old cashew crop under HMT.

Plate 5. Staggered contour trenches in Cashew Plot

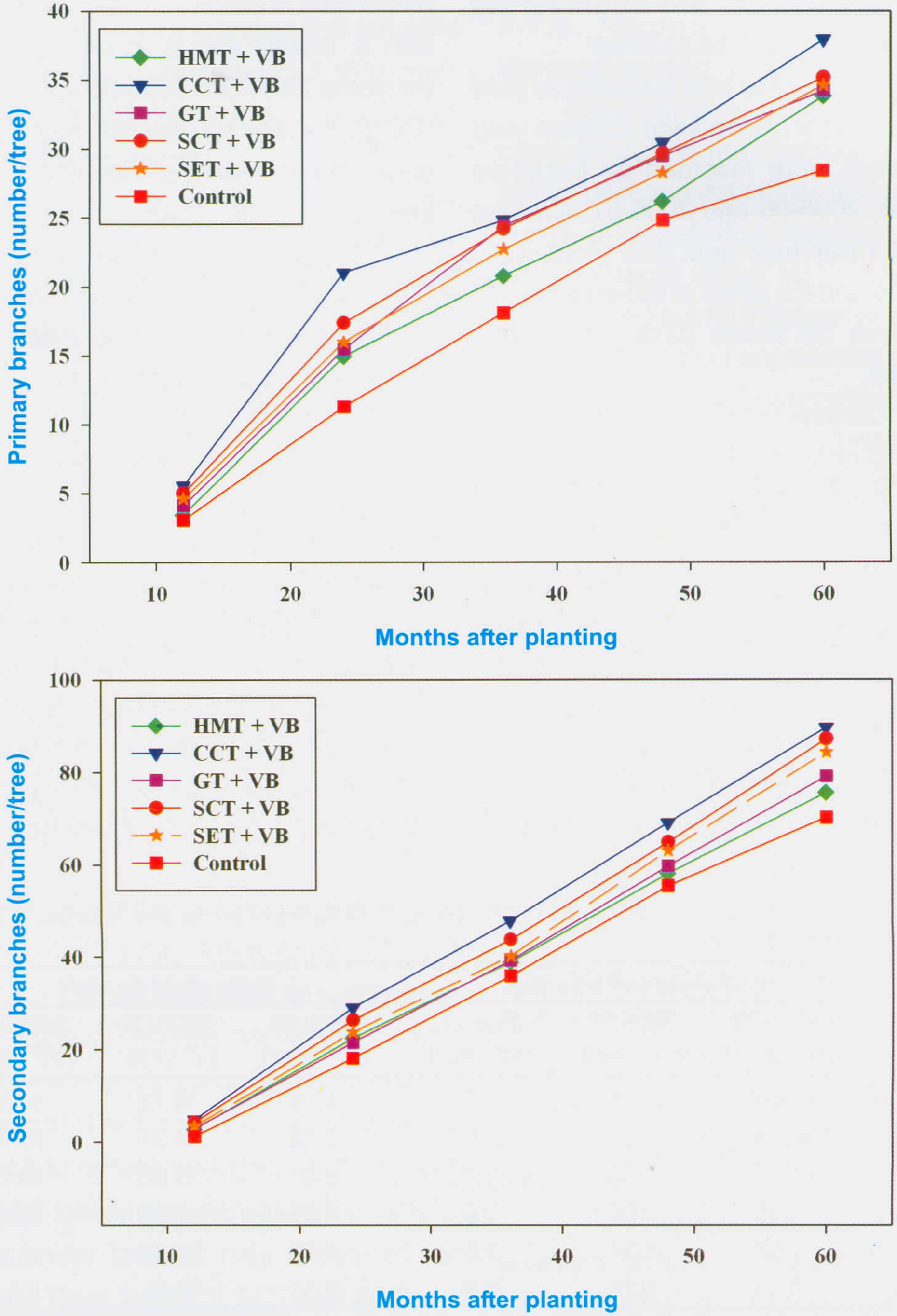


Fig. 4.3. Branching habit of cashew as affected by different bioengineering measures at various growth stages

4.1.8. Impact of bio-engineering measures on yield of cashew

The cashew plants started to yield from fourth year of plantation. Cashew yield parameters were recorded for the years 2004-05, 2005-06 and 2006-07. Average nut yield per tree and total yield were recorded and the effect of bio-engineering measures on these parameters was analyzed.

Cashew nut yield per tree and the total yield obtained during the three years period under all the conservation measures are furnished in Table 4.8. All the bio-engineering measures significantly increased the nut yield per tree as well as total yield when compared to control plot. The data were statistically analyzed and the treatments were found significant.

Maximum nut yield of 1.24, 2.27 and 2.90 kg tree^{-1} was recorded in treatment comprising of continuous contour trenches with *S. scabra* and *V. zizanioides* during the years 2004-05, 2005-06 and 2006-07 (i.e four, five and six year old cashew tress), respectively. This was followed by 1.07 kg tree^{-1} (fourth year), 2.06 kg tree^{-1} (fifth year) and 2.60 kg tree^{-1} (sixth year) in treatment comprising of SCT with *S. scabra* and *V. zizanioides.* The nut yield under GT and SET with *S. scabra* and *V. zizanioides* was on par with each other. The lowest nut yield of 0.54, 0.71 and 0.80 kg tree^{-1} during fourth, fifth and sixth years, respectively was observed in control plot where no conservation measure was adopted.

The nut yield data reveals that continuous contour trenches with live vegetative barriers increase the nut yield by 0.7 kg tree^{-1} (fourth tear), 1.56 kg tree^{-1} (fifth year) and 2.1 kg tree^{-1} (sixth year) and staggered contour trenches with

Table 4.8. Cashew yield under bio-engineering measures during the fourth, fifth and sixth year of plantation

Treatment	Nut yield per tree (kg)			Total yield (q ha^{-1})		
	2004-05 (IVth year)	2005-06 (Vth year)	2006-07 (VIth year)	2004-05 (IVth year)	2005-06 (Vth year)	2006-07 (VIth year)
HMT + VB	0.83	1.71	2.4	5.18	10.72	14.8
CCT + VB	1.24	2.27	2.9	7.72	14.21	18.1
GT + VB	1.02	1.93	2.4	6.40	12.05	15.1
SCT + VB	1.07	2.06	2.6	6.67	12.90	15.9
SET + VB	1.04	1.94	2.6	6.52	12.10	16.2
Control	0.54	0.71	0.8	3.36	4.46	5.0
CV	9.29	4.83	10.59	9.38	4.79	10.30
CD (p=0.05)	0.16	0.16	0.44	1.02	0.96	2.66

vegetative barriers increase the nut yield by 0.53 kg tree^{-1} (fourth year), 1.35 kg tree^{-1} (fifth year) and 1.8 kg tree^{-1} (sixth year), compared to control.

An increasing trend was observed in year wise yield in all the treatments. The total cashew nut yield of 7.72, 14.21 and 18.1 q ha^{-1} was recorded in treatment comprising of continuous contour trenches with *S. scabra* and *V. zizanioides* during fourth, fifth and sixth years, respectively. This was followed by 6.67 q ha^{-1} (fourth year), 12.90 q ha^{-1} (fifth year) and 15.9 q ha^{-1} (sixth year) in SCT with *S. scabra* and *V. zizanioides* treatment. Increased cashew nuts yield of 13.1, 11.2, 10.9, 10.1and 9.8 q ha^{-1}, respectively was recorded during sixth year in the treatments of CCT, SET, SCT, GT and HMT with vegetative barriers.

The lowest cashew nut yields of 3.36, 4.46 and 5.0 q ha^{-1} during fourth, fifth and sixth years, respectively was observed in control plot where no conservation measure was adopted. This showed that the soil and water conservation measures helped to reduce surface runoff, soil and nutrient losses and increased the yield of crop under lateritic hilly terrain of the region. Thus, the CCT, SCT and SET with combination of vegetative barriers could increase the cashew nut yield.

4.1.9. Economic feasibility of bio-engineering measures

Expenditure incurred towards cashew cultivation including cost of bio-engineering measures and benefits in terms of vegetation, cashew nut and cashew apple under all the treatments were worked out for initial six years period. Economic life of bio-engineering measures was assumed as 10 years with a discount rate of 20 per cent. Net present worth (NPW), benefit-cost ratio (BCR) and internal rate of return were also worked out to assess the economic feasibility of bio-engineering measures. Year wise cost and benefit details for the initial six years period are presented in Table 4.9. The total cost of establishment of bio-engineering measures and the cashew cultivation expenditure in the first year was found to be highest (Rs. 37,170 / ha) for graded trenches with vegetative barriers. The cashew cost of cultivation during the first year of the crop in CCT with vegetative barriers was Rs.35, 660 / ha. The lowest cost (Rs. 11,220 / ha) of cultivation was incurred in the plot where there was no conservation measure (control).

Investment required for first six years period towards cultivation of cashew by adopting graded trenches with vegetative barriers, continuous contour trenches with vegetative barriers and

Table 4.9 Cost and benefit details of different bioengineering measures under cashew cultivation for initial six years

Year/ Treatment	I	II	III	IV	V	VI	Total
	A. Cost stream (Rs. / ha)						
HMT + VB	23960	3125	3125	5250	5250	5250	45960
CCT +V B	35660	3125	3125	5250	5250	5250	57660
GT + VB	37170	3125	3125	5250	5250	5250	59170
SCT + VB	27170	3125	3125	5250	5250	5250	49170
SET + VB	27590	3125	3125	5250	5250	5250	49590
Control	11220	3125	3125	5250	5250	5250	33220
	B. Benefit Stream (Rs./ha)						
HMT + VB	340	1430	860	24000	51220	70500	148350
CCT +V B	710	2010	1580	39160	69310	85540	198310
GT + VB	620	1890	1390	31260	58040	72160	165360
SCT + VB	230	1290	1480	31980	62100	76240	173320
SET + VB	190	1050	1160	31200	58710	77230	169540
Control	0	0	0	15220	22620	26170	64010

staggered contour trenches with vegetative barriers was Rs. 59,170, Rs. 57,660 and Rs. 49,170 / ha, respectively. Similarly, the total expenditure required for cashew cultivation by adopting semi elliptical trenches with vegetative barriers and half moon terraces with vegetative barriers was Rs. 49, 590 and Rs. 45,960 per ha, respectively, against the least cost of Rs. 33,220 / ha required for cashew cultivation without adopting any soil and water conservation measure (control).

Benefit stream values indicate that the maximum benefit of Rs. 1, 40, 650 / ha was obtained from the cashew plot cultivated with continuous contour trenches with *S. scabra* and *V. zizanioides* followed by Rs. 1, 24, 150 / ha from field cultivated with staggered contour trenches with *S. scabra* and *V. zizanioides.* The net benefit from cashew plot cultivated by adopting semi elliptical trenches with *S. scabra* and *V. zizanioides,* graded trenches with *S. scabra* and *V. zizanioides*, and half moon terraces with *S. scabra* and *V. zizanioides* was Rs. 1, 19, 950, Rs. 1, 06, 190 and Rs. 1, 02,390 / ha, respectively against the lowest benefit Rs. 30,790 / ha obtained from the cashew plot cultivated without any soil and water conservation measure.

Benefit-cost ratio (BCR) and Internal rate of return (IRR) were also worked out by accounting for the cost and benefits for a period of 10 years and are given in Table 4.10. Maximum NPW of Rs. 4, 61, 820 / ha was obtained for cashew cultivation with continuous contour trenches with *S. scabra* and *V. zizanioides* followed by Rs. 4,08, 090 / ha under cashew cultivation with staggered contour trenches involving *S. scabra* and *V. zizanioides.* NPW of semi elliptical trenches with *S. scabra* and *V. zizanioides,* graded trenches with *S. scabra* and *V. zizanioides* and half moon terraces with *S. scabra* and *V. zizanioides* was Rs. 4, 07, 850, Rs.3, 73, 800 and Rs. 3, 63, 410 / ha, respectively. The lowest NPW (Rs. 1, 14, 450 per ha) was obtained from the cashew field cultivated without adapting any soil and water conservation measure.

BCR was maximum (6.87) in continuous contour trenches with *S. scabra* and *V. zizanioides* followed by the treatment comprising of staggered contour trenches with *S. scabra* and *V. zizanioides* (6.82) and semi elliptical trenches with *S. scabra* and *V. zizanioides* (6.78). Similarly, maximum IRR of 20 % was obtained in the treatment continuous contour trenches followed by 18 per cent of IRR in the treatments comprising of staggered contour trenches with *S. scabra* and *V. zizanioides* and semi elliptical trenches with *S. scabra* and *V. zizanioides.* Lowest BCR (3.11) and IRR (10 per cent) were obtained from the cashew field cultivated without soil and water conservation measure.

Table 4.10. Net present worth, benefit cost ratio and internal rate of return of different bio-engineering measures adopted for cashew crop

Conservation measure	NPW (Rs./ha)	BCR	IRR (%)
Half moon terraces with *S. scabra* and *V. zizanioides*	3,63,410	6.43	16.0
Continuous contour trenches with *S. scabra* and *V. zizanioides*	4,61,820	6.87	20.0
Graded trenches with *S. scabra* and *V. zizanioides*	3,73,800	5.66	16.0
Staggered contour trenches with *S. scabra* and *V. zizanioides*	4,08,090	6.82	18.0
Semi elliptical trenches with *S. scabra* and *V. zizanioides*	4,07,850	6.78	18.0
Without conservation measure	1,14,450	3.11	10.0

4.2. Experiment II

4.2.1. Annual runoff

The annual rainfall received and the observed runoff values for the study period are given in Table 4.11. Minimum runoff (190.8 mm, 218.7 mm, 213.3 mm, 274.9 mm and 376.5 mm, respectively) was recorded during 2002 to 2006 under the treatment of continuous contour trenches with vegetative barrier of *S. scabra* and *G. maculata*. The mean runoff of five years revealed that minimum runoff of 320.6 mm was produced in plots with continuous contour trenches and vegetative barrier of *S. scabra* and *G. maculata* followed by 391.2 mm in staggered contour trenches with *S. scabra* and *G. maculata* and 426.1 mm in crescent shape trenches with *S. scabra* and *G. maculata* and 523.4 mm in *S. scabra* and *G. maculata* against the mean runoff of 595.3 mm produced in the control plot.

The runoff varied from 8.3 to 21.4 per cent of the annual rainfall under conservation practices whereas it was 16.1 to 24.0 per cent in control plot. Runoff per cent under continuous contour trenches with vegetative barrier of *S. scabra* + *G. maculata* reduced to 10.9 per cent of total rainfall from 20.3 per cent under control thus showing reduction of 46.3 per cent. Similarly, staggered contour trenches with *S. scabra* and *G. maculata* and crescent shape trenches with *S. scabra* and *G. maculata* showed a reduction of runoff by 35.0 and 29.0 per cent, respectively. This reduction in runoff under different bio-engineering measures was attributed to their impact, which reduces runoff velocity and increases infiltration opportunity time for water.

Table 4.11. Annual runoff under different soil and water conservation measures

Year	Rainfall (mm)	Runoff (mm)				
		CCT + VB	SCT + VB	CST + VB	VB alone	Control
2002	2312.5	190.8	218.7	213.3	274.9	376.5
2003	3124.2	398.7	481.2	543.0	668.9	724.8
2004	2432.9	221.6	250.1	297.9	354.8	391.9
2005	3269.1	424.0	536.8	563.5	695.9	784.6
2006	3217.0	367.9	469.0	512.9	622.7	698.7
Mean	**2871.1**	**320.6**	**391.2**	**426.1**	**523.4**	**595.3**

Table 4.12. Percentage of runoff to rainfall under different conservation measures

Year	Runoff (mm)				
	CCT + VB	SCT + VB	CST + VB	VB alone	Control
2002	8.3	9.5	9.2	11.9	16.3
2003	12.8	15.4	17.4	21.4	23.2
2004	9.1	10.3	12.2	14.6	16.1
2005	13.0	16.4	17.2	21.3	24.0
2006	11.4	14.6	15.9	19.4	21.7
Mean	**10.9**	**13.2**	**14.4**	**17.7**	**20.3**

4.2.2. Soil loss

The annual soil loss was monitored for five years period (2002-2006) and furnished in Table 4.13. More soil loss was recorded in all the treatments during the year 2002 and reduced in subsequent years. This may be due to the disturbance of topsoil by planting operations in initial year. As the soil stabilized in subsequent years, the soil losses were reduced. Overall, conservation practices reduced the soil loss by 3.1 to 6.5 t ha^{-1} per year. Continuous contour trenches with vegetative barrier of *S. scabra* + *G. maculata* showed significant reduction in average soil loss (1.8 t ha^{-1}) followed by staggered contour trenches with *S. scabra* and *G. maculate* (2.7 t ha^{-1}) and crescent shape trenches + *S. scabra* and *G. maculata* (2.9 t ha^{-1}) as compared to the control plot, while a soil loss of 8.3 t ha^{-1} was recorded under the control plot.

Table 4.13. Annual soil loss as influenced by different bio-engineering measures

Year	Soil loss (t ha^{-1} yr^{-1})				
	CCT + VB	SCT + VB	CST + VB	VB alone	Control
2002	3.1	4.3	4.3	8.5	12.9
2003	2.3	3.4	3.8	6.9	10.4
2004	1.5	2.7	3	4.2	7.9
2005	1.1	1.7	1.8	3.4	5.3
2006	0.8	1.5	1.6	3	4.9
Mean	**1.8**	**2.7**	**2.9**	**5.2**	**8.3**

4.2.3. Nutrient loss

Data on nutrient losses (Table 4.14) revealed that all the conservation measures reduced nutrient losses as compared to control plot. The mean values indicate that minimum nitrogen loss was 11.7 kg ha^{-1} in the treatment of continuous contour trenches with vegetative barrier of *S. scabra* + *G. maculata* followed by 15.8 kg ha^{-1} in the plot with staggered contour trenches and *S. scabra* + *G. maculata* while the maximum nitrogen loss (29.1 kg ha^{-1}) was recorded in control plot. Similarly, potassium losses were minimum (17.9 kg ha^{-1}) in the treatment of continuous contour trenches with *S. scabra* + *G. maculata* followed by 21.7 kg ha^{-1} in the treatment of staggered contour trenches with *S. scabra* + *G. maculata* as against the maximum potassium loss of 42.2 kg ha^{-1} recorded in control plot.

Phosphorus loss varied from 0.1 to 0.2 kg ha^{-1} in all the treatments, which may be due to the nature of phosphorus which does not move in runoff as fast as other nutrients. The soil and nutrient loss data shows that the continuous contour trenches with vegetative barrier of *S. scabra* + *G. maculata* was the best conservation practice to reduce the soil and nutrient loss among all the conservation treatments.

4.2.4. Soil, water and soil & water conservation efficiencies

Soil conservation efficiency, water conservation efficiency and soil and water conservation efficiency were worked out during each year and the values are given in Table 4.15. The highest water conservation efficiency (WCE) of 49.3, 45.0, 43.5, 46.0 and 47.3 per cent were recorded in continuous contour trenches with *S. scabra* + *G. maculata* during the years 2002, 2003, 2004, 2005

Table 4. 14. Nutrient loss under different conservation practices (kg ha^{-1})

Treatment	2002			2003			2004			2005			2006			Mean		
	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K	N	P	K
CCT + VB	15.4	0.02	27.2	13.0	0.1	20.5	11.0	0.1	16.4	9.0	0.2	14.0	10.0	0.2	11.4	11.7	0.1	17.9
SCT + VB	22.5	0.03	35.4	18.9	0.1	25.7	14.3	0.1	20.3	11.3	0.3	14.7	11.9	0.2	12.6	15.8	0.2	21.7
CST + VB	22.8	0.03	38.1	20.2	0.1	26.7	16.0	0.1	22.7	13.5	0.3	18.0	13.0	0.2	16.0	17.1	0.2	24.3
VB alone	31.0	0.04	36.7	19.8	0.2	29.8	18.7	0.2	25.8	16.0	0.4	19.0	17.0	0.3	15.5	20.5	0.2	25.4
Control	42.7	0.04	73.2	32.2	0.2	53.4	27.4	0.2	39.7	23.2	0.4	24.8	19.8	0.3	20.1	29.1	0.2	42.2

Table 4.15. Water, soil and soil and water conservation efficiencies of different bioengineering measures

Year	CCT + VB	SCT + VB	CST + VB	VB alone
	Water conservation efficiency (%)			
2002	49.3	41.9	43.3	27.0
2003	45.0	33.6	25.1	7.7
2004	43.5	36.2	24.0	9.5
2005	46.0	31.6	28.2	11.3
2006	47.3	32.9	26.6	10.9
Mean	**46.2**	**35.2**	**29.4**	**13.3**
	Soil conservation efficiency (%)			
2002	76.0	66.7	66.7	51.8
2003	77.9	67.3	63.5	33.7
2004	81.0	65.8	62.0	46.8
2005	79.2	67.9	66.0	35.8
2006	83.7	69.4	67.3	38.8
Mean	**79.6**	**67.4**	**65.1**	**41.4**
	Soil and water conservation efficiency (%)			
2002	62.6	54.3	55.0	39.4
2003	61.4	50.5	44.3	20.7
2004	62.2	51.0	43.0	28.2
2005	62.6	49.8	47.1	23.6
2006	65.5	51.1	47.0	24.8
Mean	**62.9**	**51.3**	**47.3**	**27.3**

and 2006, respectively. The mean values of water conservation efficiency of continuous contour trenches with *S. scabra* + *G. maculata,* staggered contour trenches with *S. scabra* + *G. maculata* and crescent shape trenches with *S. scabra* + *G. maculata* were 46.2, 35.2 and 29.4 percent, respectively.

The average SCE of continuous contour trenches with *S. scabra* + *G. maculata*, staggered contour trenches with *S. scabra* + *G. maculata*, crescent shape trenches with *S. scabra* + *G. maculata* and *S. scabra* + *G. maculata* alone were 79.6, 67.4, 65.1 and 41.4 %, respectively. By and large the highest soil and water conservation efficiency was observed in continuous contour trenches with *S. scabra* + *G. maculata* (62.9 per cent) followed by staggered contour trenches with *S. scabra* + *G. maculata* (51.3 per cent) and it was the lowest (27.3 per cent) in *S. scabra* + *G. maculata* alone.

4.2.5. Soil moisture content

The soil moisture content at 30, 60 and 90 cm depths were monitored at periodical intervals after cessation of monsoon and the mean data for five years are furnished in Table 4.16. The maximum soil moisture content of 12.8 per cent at 30 cm soil depth was recorded under continuous contour trenches with *S. scabra* + *G. maculata* followed by staggered contour trenches with *S. scabra* + *G. maculata* (11.8 per cent) against 8.0 per cent soil moisture content observed in control plot during the month of May. Similar trend was observed at 60 and 90 cm soil depths. It could be inferred that the in-situ conservation measures increase and retain the soil moisture till the month of May. This can be attributed to comparatively less runoff and more intake of water in to the soil profile. Further, the results reveal that the continuous contour trenches with *S. scabra* + *G. maculata* was found to be the best conservation measure to retain soil moisture for longer duration after cessation of monsoon.

Table 4. 16. Effect of in-situ moisture conservation measures on soil moisture content at different soil depths

Treatment	Soil depth (cm)	Soil moisture content (per cent)			
		November	January	March	May
CCT + LB	0-30	26.3	20.2	16.2	12.8
	30-60	27.1	20.7	16.8	13.2
	60-90	27.5	21.6	17.2	13.7
SCT + LB	0-30	26.5	18.9	14.5	11.8
	30-60	27.2	19.5	15.6	12.7
	60-90	27.8	20.3	16.2	13.0
CST + LB	0-30	25.2	18.4	14.8	11.1
	30-60	25.9	19.2	15.4	11.7
	60-90	26.2	19.6	15.8	12.1
LB	0-30	22.0	15.3	11.9	9.0
	30-60	22.5	16.0	12.6	9.2
	60-90	23.0	17.0	12.8	9.5
Control plot	0-30	21.8	14.6	10.5	8.0
	30-60	22.2	14.8	10.9	8.7
	60-90	22.7	15.1	11.2	9.0

CCT - Continuous Contour Trench
SCT - Staggered Contour Trench
CST - Crescent Shape Trench

LB (Live barrier) - *Stylosanthes scabra* + *Gliricidia maculata*

4.2.6. Growth performance of cashew

In general, all the conservation measures improved the survival, establishment and growth of cashew plants when compared to the control plot. Maximum survival of 89.4 per cent cashew was recorded in conservation measures with continuous contour trenching and vegetative barrier followed by staggered contour trenching with vegetative barrier (80 %) against a survival of 55 per cent in the control plot (Fig 4.4.).

Data on growth parameters of cashew plants *viz.* height, girth and branching recorded at periodic intervals from 12 months to 36 months after planting indicated that the various conservation measures influenced growth of cashew plants. Plants grown under continuous contour trenches and staggered contour trenches along with vegetative barrier recorded better growth parameters in terms of mean plant height (316.7 and 300 cm), girth of the plant (35.1 and 32.2 cm) and branching habit (21 and 20 primary branches and 43 and 49 secondary branches per plant) at 36 months after planting as compared to other conservation treatments and control (Fig 4.5 and 4.6). Although, initially the impact of these treatments was not evident, the impact began to be visible after12 months of planting. The overall growth performance indicates that the continuous contour trenches with *S. scabra* + *G. maculata* influenced the growth of cashew in the initial stages, which may be attributed to the retention of more soil moisture in these treatments, which in turn has reflected in better growth of the plants.

Plate 6. Cashew in between two rows of CCT with gliricidia as vegetative barrier

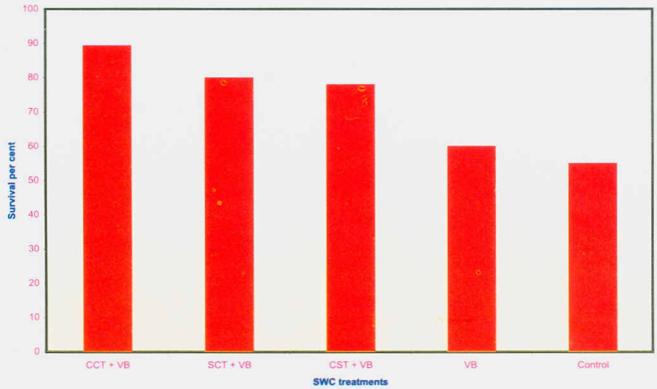
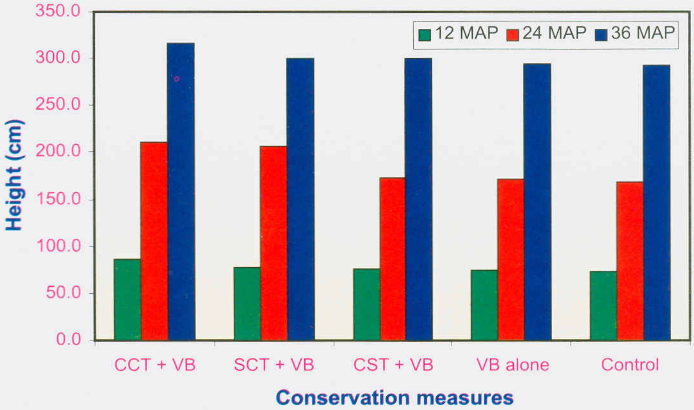


Fig. 4.4. Survival percentage of cashew plants under different conservation measures



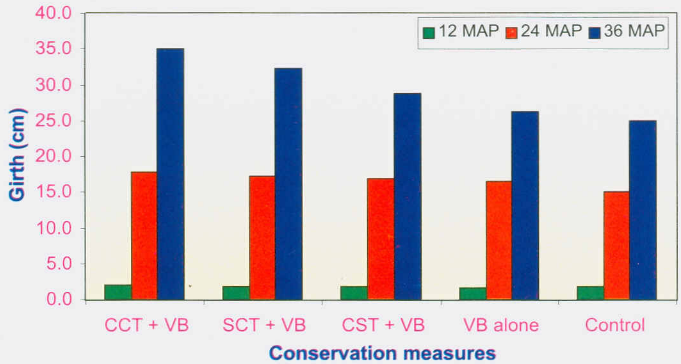


Fig. 4.5. Effect of soil and water conservation measures on growth (height and girth) of cashew

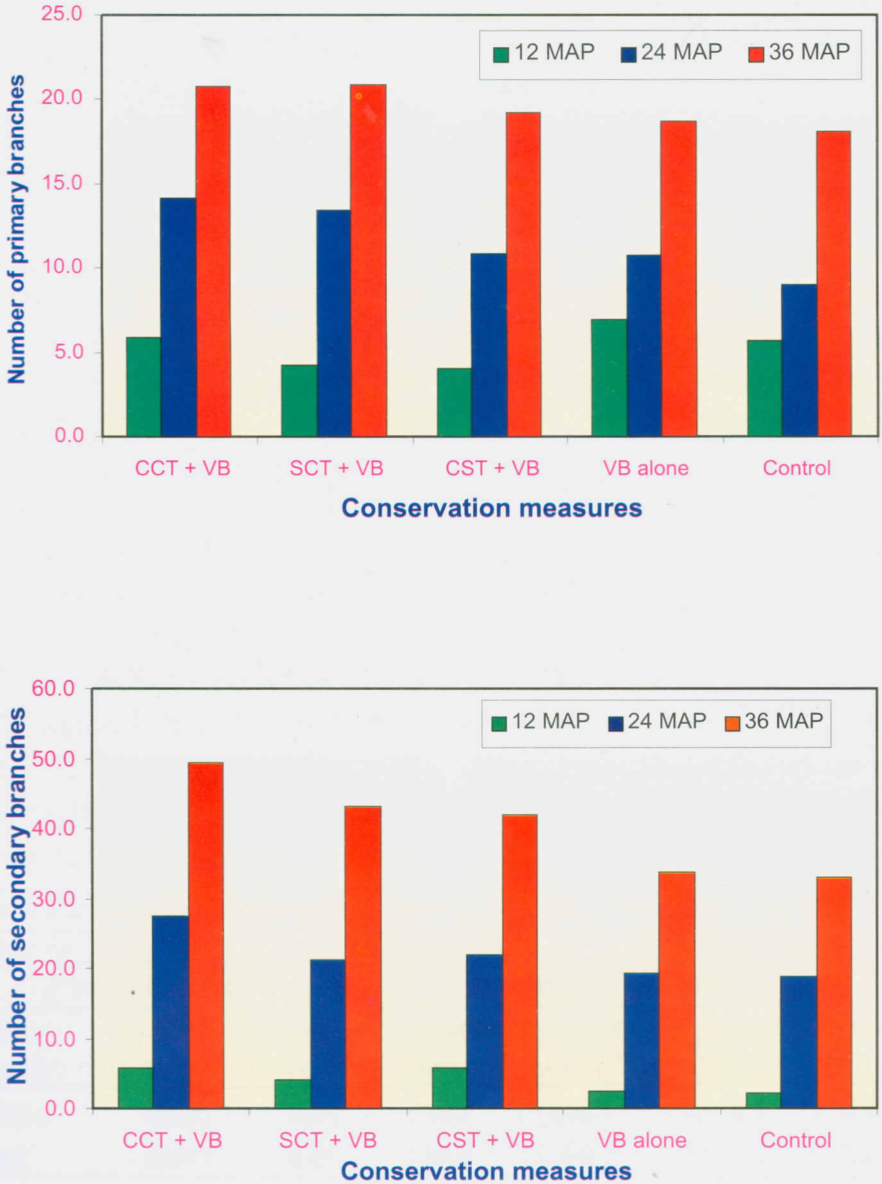


Fig. 4.6. Branching habit of cashew under different conservation measures

4.2.7. Impact of bio-engineering measures on yield of cashew

The cashew plants commended yielding from fourth year of plantation. Cashew yield parameters were recorded from fourth to sixth years (2004-05, 2005-06 and 2006-07). Average nut yield per tree and total yield per hectare area were recorded and the effect of conservation measures on these parameters was analyzed.

Cashew nut yield per tree and the total yield per hectare obtained during the three years period under all the conservation measures are furnished in Table 4.17. All the *in- situ* moisture conservation measures significantly increased the nut yield per tree as well as total yield when compared to control plot. The data were statistically analyzed and the treatments were found significant.

Maximum nut yields of 2.5, 1.2 and 1.9 kg tree^{-1} were recorded in treatment comprising of continuous contour trenches with *S. scabra* + *G. maculata* during fourth, fifth and sixth year, respectively. This was followed by 2.0 kg tree^{-1} (fourth year), 1.0 kg tree^{-1} (fifth year) and 1.40 kg tree^{-1} (sixth year) in treatment comprising of SCT with *S. scabra* + *G. maculata.* The lowest nut yields of 1.1, 0.6 and 0.8 kg tree^{-1} fourth, fifth and sixth year, respectively were observed in control plot where no conservation measure was adopted. The nut yield in all the treatments was in satisfactory in 2006 and 2007 due to infestation of tea mosquito bug.

The total cashew nut yield of 6.80, 3.50 and 5.20 q ha^{-1} were recorded in treatment comprising of continuous

Table 4.17. Cashew yield under different conservation measures during the fourth, fifth and sixth year of plantation

Treatment	Nutyield per tree (kg)			Total yield (q ha^{-1})		
	2004-05 (IVth year)	2005-06 (Vth year)	2006-07 (VIth year)	2004-05 (IVth year)	2005-06 (Vth year)	2006-07 (VIth year)
CCT + VB	2.5	1.2	1.9	6.8	3.5	5.2
SCT + VB	2.0	1.0	1.4	5.6	2.8	3.9
CST + VB	1.8	0.9	1.2	4.9	2.4	3.2
VB alone	1.3	0.7	0.9	3.5	2.0	2.5
Control	1.1	0.6	0.7	3.0	1.6	2.0
CV	15.6	17.1	15.9	15.2	16.4	15.0
CD p (0.05)	0.51	0.28	0.37	1.36	0.76	0.96

contour trenches with *S. scabra* + *G. maculata* during fourth, fifth and sixth years, respectively. This was followed by 5.60 q ha^{-1} (fourth year), 2.80 q ha^{-1} (fifth year) and 3.90 q ha^{-1} (sixth year) in SCT with *S. scabra* + *G. maculata* treatment. The increased cashew nut yield of 3.2, 1.9, and 1.2 q ha^{-1}, respectively were recorded during sixth year in the treatments of CCT, SCT and CST with vegetative barriers. Live barrier of *S. scabra* + *G. maculata* alone could increase the yield of 0.5 q ha^{-1} during sixth year. The lowest cashew nut yields of 3.0, 1.6 and 2.0 q ha^{-1} during fouth, fifth and sixth years, respectively was observed in control plot where no conservation measure was adapted. This showed that the soil and water conservation measures helped to reduce surface runoff, soil and nutrient losses and increased the yield of crop under lateritic hilly terrain of the region. It could be drawn from above observations that CCT, SCT and CST with combination of vegetative barriers could increase the cashew nut yield.

4.2.8. Economic feasibility of conservation measures

Year wise cost and benefit details for the initial six years period are given in Table 4.18. The total cost of establishment of bio-engineering measures and the expenditure incurred on cashew cultivation in the first year was found to be highest (Rs. 21, 340 / ha) for continuous contour trenches with vegetative barriers. The cost of cultivation during the first year of the crop in SCT and CST with vegetative barriers

Table 4.18. Cost and benefit details of different bio-engineering measures under cashew cultivation for initial six years

Year	I year	II year	III year	IV year	V year	VI year	Total
Treatment			A.Cost stream (Rs. / ha)				
CCT +V B	21340	1385	1385	2350	2350	2350	31160
SCT + VB	15680	1385	1385	2350	2350	2350	25500
CST+ VB	12300	1385	1385	2350	2350	2350	22120
VB alone	6000	1385	1385	2350	2350	2350	15820
Control	5040	1385	1385	2350	2350	2350	14860
			B. Benefit Stream (Rs./ ha)				
CCT +V B	1780	2480	2030	34950	20390	28769	90400
SCT + VB	1640	2220	1230	29560	16930	22100	73680
CST + VB	1510	2180	1700	25460	15100	18950	64900
VB alone	1410	1900	1730	17160	12330	11960	46490
Control	0	0	0	13520	7730	9290	30540

was Rs.15, 680 and Rs.12, 300 / ha, respectively. The lowest cost of cultivation (Rs. 5,040 / ha) was incurred in the plot where there was no conservation measure.

The total cost of investment required for first six year periods towards cultivation of cashew by adopting continuous contour trenches with vegetative barriers, staggered contour trenches with vegetative barriers and crescent shape trenches with vegetative barriers was Rs. 31,160, Rs. 25, 500 and Rs. 22,120 / ha, respectively. Similarly, the total cost required for cashew cultivation by adopting vegetative barriers alone was Rs. 15, 820 / ha against the least cost of Rs. 14, 860 / ha required for cashew cultivation without adopting any soil and water conservation measure.

Benefit stream values indicate that the maximum net benefit of Rs. 59, 240 / ha was obtained from the cashew field cultivated with continuous contour trenches with *S. scabra* + *G. maculata* followed by Rs. 48, 180 / ha from field cultivated with staggered contour trenches with *S. scabra* + *G. maculata*. The net benefit from cashew plot cultivated by adopting crescent shape trenches with *S. scabra* + *G. maculata* and *S. scabra* + *G. maculata* alone was Rs. 42, 780 and Rs. 30, 670 / ha, respectively against the lowest benefit Rs. 15, 680 / ha obtained from the cashew field cultivated without any soil and water conservation measure.

Benefit-cost ratio (BCR) and Internal rate of return (IRR) were also worked out by accounting for the cost and benefits for a period of 10 years and are given in Table 4.19. Maximum NPW of Rs. 1, 64, 900 / ha was obtained under

Table 4.19. Net present worth, benefit cost ratio and internal rate of return of different bio-engineering measures adopted for cashew crop

Conservation measures	NPW (Rs. / ha.)	BCR	IRR (%)
Continuous contour trench + *S. scabra* + *G. maculata*	1,64,900	5.07	13.0
Staggered contour trench + *S. scabra* + *G. maculata*	1,27,190	4.64	12.5
Crescent shape trench + *S. scabra* + *G. maculata*	1,09,130	4.46	11.0
S. scabra + *G. maculata* alone	69,090	3.74	10.0
Without conservation measures	43,410	2.79	10.0

cashew cultivation with continuous contour trenches with *S. scabra* + *G. maculata* followed by Rs. 1,27,190 / ha under cashew cultivation with staggered contour trenches *S. scabra* + *G. maculata.* The lowest NPW (Rs. 43,410 / ha) was obtained from the cashew field cultivated without adapting any soil and water conservation measure.

BCR was maximum (5.07) in continuous contour trenches with *S. scabra* + *G. maculata* followed by the treatment comprising of staggered contour trenches with *S. scabra* + *G. maculata* (4.64) and crescent shape trenches with *S. scabra* + *G. maculata* (4.46). Similarly, maximum IRR of 13 per cent was obtained in the treatment of continuous contour trenches followed by 12.5 per cent of IRR in the treatments comprising of staggered contour trenches with *S. scabra* + *G. maculata*. The least BCR (2.79) and IRR (10 %) were obtained from the cashew field cultivated without soil and water conservation measure.

5. CONCLUSIONS

Six years field data generated through two sets of experiments, one with 4 X 4 m and with 6 x 6 m spacing of cashew plantation with different bio-engineering measures clearly indicates that there was significant reduction on runoff, soil loss, nutrient loss and increase in crop growth and yield of cashew. Salient conclusions drawn from the study are as follows:

- Continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* and staggered contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* reduced the runoff by 44.5 and 34.6 per cent, respectively under spacing of 4m X 4m cashew plantations. Similarly, continuous contour trenches with vegetative barrier of *Stylosanthes scabra + Gliricidia maculata,* staggered contour trenches with *Stylosanthes scabra* and *Gliricidia maculata* and crescent shape trenches with *Stylosanthes scabra* and *Gliricidia maculata* recorded runoff reduction of 46.3, 35 and 29.0 per cent, respectively in the field where cashew was planted at 6 m x 6m spacing.
- Continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* and staggered contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* reduced the soil loss by 11.3 and 8.1 t ha^{-1} yr^{-1} in 4 m x 4 m cashew field. Similarly, continuous contour trenches with vegetative barrier of *Stylosanthes scabra + Gliricidia maculata* significantly reduced average soil loss (6.5 t ha^{-1}) followed by staggered contour trenches with *Stylosanthes scabra* and *Gliricidia maculata* (5.6 t ha^{-1}) and crescent shape trenches + *Stylosanthes scabra* and *Gliricidia maculata* (5.7 t ha^{-1}) in the plot where the cashew was planted at 6 m x 6 m spacing.
- Continuous contour trenches with vegetative barriers was the best when compared to all other treatments as far as nutrient loss reduction was concerned. Staggered contour trenches with vegetative barriers were found as the next best treatment in reducing the nutrients loss under cashew crop.
- Highest soil and water conservation efficiency was observed in continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* (49.5 %) followed by staggered contour

trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* (37.1 %) under 4 m X 4 m cashew plantations. Similarly, maximum soil and water conservation efficiency was observed in continuous contour trenches with *Stylosanthes scabra* + *Gliricidia maculata* (62.9 per cent) followed by staggered contour trenches with *Stylosanthes scabra* + *Gliricidia maculata* (51.3 per cent) in the plot where cashew was planted at 6 m x 6m spacing.

- Soil and water conservation measures increase and retain the soil moisture till the month of May. Continuous contour trench with vegetative barriers was found to be the best conservation measure to retain soil moisture for longer duration after cessation of monsoon. Alternatively, the staggered contour trench with vegetative barrier was found to be better in retaining soil moisture.

- All the conservation measures significantly increased the growth and yield of cashew. Continuous contour trenches and staggered contour trenches with vegetative barriers recorded the maximum plant growth and yield.

- Total cashew nut yield of 7.72, 14.21 and 18.1 q ha^{-1} were recorded in treatment comprising of continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* during fourth, fifth and sixth years, respectively under 4 m X 4 m cashew plantations. The total cashew nut yield of 6.80, 3.50 and 5.20 q ha^{-1} were recorded in treatment comprising of continuous contour trenches with *Stylosanthes scabra* + *Gliricidia maculata* during fourth, fifth and sixth years, respectively under 6 m X 6 m plantations.

- Maximum NPW of Rs. 4, 61, 820 per ha was obtained under cashew cultivation with continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* followed by Rs. 4,08, 090 per ha under cashew cultivation with staggered contour trenches *Stylosanthes scabra* and *Vetiveria zizanioides.* Maximum NPW of Rs. 1, 64, 900 per ha was obtained under cashew cultivation with continuous contour trenches with *Stylosanthes scabra* + *Gliricidia maculata* followed by Rs. 1,27,190 per ha under cashew cultivation with staggered contour trenches *Stylosanthes scabra* + *Gliricidia maculata.*

- Higher benefit cost ratio and Internal rate of return were obtained under the continuous contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* (6.87 and 20 %, respectively) followed by staggered contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* (6.82 and 18 per cent, respectively) under 4 x 4 m cashew plantation. Similarly, BCR and IRR were higher under the continuous contour trenches with *Stylosanthes scabra* and *Gliricidia maculata* (5.07 and 13 %, respectively) followed by the staggered contour trenches with *Stylosanthes scabra* and *Gliricidia maculata* (4.64 and 12.5 %, respectively) under 6 m X 6 m cashew plantations.

In summary, it could be concluded that the continuous contour trenches with vegetative barriers was the best as compared to all other treatments for runoff, soil loss and nutrient loss reduction. Staggered contour trenches with *Stylosanthes scabra* and *Vetiveria zizanioides* was the alternative measure for reduction of runoff and soil loss for cashew land use. Additional income could be generated from the vegetative barriers, which can be used as either fodder or biomass during the initial periods of cashew plantation by adapting the bioengineering measures. Continuous contour trenches with vegetative barriers and staggered contour trenches with vegetative barriers were found economically viable and these technologies are recommended for adoption in the cashew plantations in hilly terrain.

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