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Economics of eucalyptus: Shifting from traditional farming to income based farming

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Abstract
Agroforestry system as an ecological sustainable land use option alternative to the prevalent subsistence farming patterns for conservation and development. It is an old traditional practice but recently named as an Agroforestry. A large area is available in the form of boundaries, bunds, block plantation, wastelands where this system can be adopted.
The main purpose of this review to provide/generates an idea about how Eucalyptus behaves with associated crops, i.e interaction between both components. Both components are studied in many aspects, comprises outcome of yield which depends upon the age of trees; along with nutritional studies of Eucalyptus at various age groups.
Litter production is also higher in trees intercropped than trees which are without any intercrops.
In the study of nutrients (NPK) it is reviewed that all the three nutrients increase as the age of trees increases.
The extent of enrichment in soil properties depends on tree species, management practices and the quantity and quality of litter and their decay rate. Moreover, the leaf litter deposition from Eucalyptus vegetation and resultant soil acidity might also affected intercrop yield.
Further, litterfall and decomposition are the two major processes responsible for soil enrichment in agroforestry systems.
In the study it is observed that nutrient contents of soil, after eight years of duration, is higher in sole Eucalyptus than the intercropped fields.
As the depth increases, N and K are decreased in sole as well as in intercropped fields.
Yield of all the intercrops is low in the fields which are cultivated along with trees.
This suggested that trees of Eucalyptus should be harvested during 7-8 years of age, for getting more income.
So, if Farmer grow Eucalyptus as a sole, he will get Net Profit of Rs. 2057672=00 and if it is grown with wheat, cereals and Aromatic crops from initial stage to 8 years of age than a farmer can get Rs. 3163385=24,only.

Keywords: Litter, Nutrient, Breast height, cultural operations, soil cultivation, vegetation

Introduction
Agroforestry system as an ecological sustainable land use option alternative to the prevalent subsistence farming patterns for conservation and development. It is an old traditional practice but recently named as an Agroforestry. A large area is available in the form of boundaries, bunds, block plantation, waste lands; where this system can be adopted. (Abhishek *et al*. 2016) [1].

The main purpose of this review to provide/generates an idea about how Eucalyptus behaves with associated crops, i.e interaction between both components. Both components are studied in many aspects, comprises outcome of yield which depends upon the age of trees; along with nutritional studies of Eucalyptus at various age groups.

Agroforestry not only benefit farmers, it also supplies raw material to wood industry, generate employment of various kinds thus benefiting millions in related economic activities like transportation, wholesale, retailing, etc. It helps consumers with an affordable supply of wood and contributes to import subsititution for timber and timber related products, which India imports worth thousands of crores of rupees a year.

Also agroforestry is as good, if not better, than degraded forests for environmental improvement, pollution control, etc, especially as it can be initiated in farmers' holdings in villages and nearer to urban conglomerations. It is a win-win situation for all.

Roots provide anchorage for the tree and serve the vital functions of absorption and translocation of water and nutrients.

They exert a significant influence on soil profile development, and upon dying, roots contribute to soil organic matter content (McClaugherty *et al.*1982) [18].

The difficulty in predicting the rooting pattern and root interaction of woody species in agroforestry is further compounded by the fact that the root systems of most tropical trees have been only scantily investigated (Halle *et al*., 1978) [11]. Some of the reviews that are available on the work (Kerfoot, 1963; Jenik, 1977) [16, 14] indicate that for many woody species the largest number of roots, are located in the uppermost fertile portion of the soil profile.

Spatial distribution and biomass of roots in E.camaldulensis (Prasad *et al*., 1984; Zohar, 1985) [30, 40], E. grandis (Baldwin and Stewart, 1987) [3], E. hybrid (Dabral *et al*., 1987) [6], E.tereticornis (George, 1985 and Dhyani *et al.*, 1990) [9, 7], E.marginata (Carbon *et al.*, 1980) [4] and E. globules (Mathur *et al.*, 1984) plantation were studied.

Materials and Methods

Field experiment was conducted at farmers field for Eight years (2011 to 2019) in Distt. Pilibhit of Tarai and Bhabar region of U.P. Maximum and minimum temperature ranges from 22 to45 C and 8.10 to 28.10 C, respectively. The soil of sites was a Typic Hapludoll derived from alluvium. It is a silty clay loam having pH of 7.1, organic carbon 1.0%, available N,P and K are 271.5,11.8 and 243.4 kg/ha, respectively.

Planting of Eucalyptus was done in the last week of june 2011 at the spacing of 4m x 2m and harvesting in the month of November-2019.

The study was conducted in Distt. Pilibhit; one of the most important Districts in terms of area and production of all the crops mentioned above.

Two villages, each was selected from each selected block, randomly. A pooled list of all the growers was prepared for all the selected villages.

A sample of 60–growers was obtained from the selected villages using probability proportion to size method, with a restriction that a minimum of 15- farmers represent each size group.

Sowing of Urd (PU-31) was also done in the month of June 2011 and its harvesting in October 2011. In November 2011, Wheat (HD- 2967) was sown and its harvesting in April 2012; followed by sowing of Moong (Pant Moong-5) in June 2012 with its harvesting in October 2012.

For *Mentha arvensis* (Kosi) and *Mentha piperita* (kukrail), the whole plot of 1- hectare was divided into two equal parts. Cultivation of Mentha suckers was done in February 2013 with its harvesting in the month of May 2013.

After harvesting of Mentha spp., again Urd and Wheat was taken in the same fields; with its sowing in June 2013 and November 2013, respectively. For Aromatic grasses, the whole plot was divided in three equal parts.Three aromatic grasses; C. winterianus, C. martini and C. flexuouses (mandakni, PRC-1, Krishna) were cultivated in the month of June- 2014. These aromatic grasses continued for four years with various harvests, i.e., upto November 2018.

The crops was irrigated as per need and subsequent irrigations were provided to the crops. The fertilizer doses for all the crops were given as per recommendation.

Harvest of Mentha crops was taken after 120 days of planting. Fresh herbage yield of Mentha and Aromatic grasses were recorded in each harvest by quadrat method. A sample of each crop at harvest was collected and oil content was measured with the help of clevenger's apparatus. Oil yield was calculated by multiplying fresh herbage yield with oil content. Diameter of the trees was measured at breast height (1.37m) and height was measured by Ravi multimeter, each year during the period of study. The annual litterfall production of the trees in intercropping stands was recorded by collecting all the leaves and twigs, falling to the soil surface in litter traps made by demarcating 100cm x 100cm areas at 6 places (two places each at South, North and Central position of line). The litter samples collected were pooled together to represent annual fall and oven dried at 80 C for 36 hrs and subjected to further chemical analysis for N,P,K, using the modified microkjeldahl, Vanadomolybdophosphoric acid yellow colour method and flame photometry, respectively (Jackson, 1967) [12]. Total addition of nutrients to the soil through litterfall (kg/ha/yr) was also calculated. The available nitrogen in soil was estimated by the method by Subbiah and Asija (1956) [37] using 0.32% KmNo4 and 2.5% boric acid having a mixed indicator.

The available phosphorus in the soil was determined by Olsen's bicarbonate method and the available potassium was extracted from the soil by neutral normal ammonium acetate as described by Jackson (1967) [12].

Economics of Eucalyptus plantation was calculated at survival rate of 90% of trees (1125 trees of 1250 trees). 50% of trees (563) were harvested in the form of 'Bali' at the age of 5 years, and remaining (562) trees were harvested at the age of 8 years, in the form of Over size and under size wood and Sokta and Fuelwood.

The pattern of root distribution of the Eucalyptus trees was studied by excavation method as reported by Ghosh and Chattopadhyay (1972) and Chandra *et al.* (1979) [10, 5]. A circle of 150cm radius was marked around the tree trunk and further sub-divided into three radial distances, of 0-50, 50-100 and 100-150 cm. from the center of the tree base. Each of the radial distances was further sub-divided into various soil depths, of 0-15,15-45,45-75 and 75-105 cm.

The roots were graded into following four classes (Aiyappa and Srivastava, 1965) [2], on the basis of their diameter measured with the help of vernier calipers.

1. g1 (Fibrous) = < 0.2cm
2. g2 (Thin) = 0.2- 0.5cm
3. g3 (Medium) = 0.5 – 1.5cm
4. g4 (Thick) = > 1.5 cm.

In the last year of study; in the month of November-2019, the whole block plantation of Eucalyptus was harvested successfully.

Results and Discussion

In the present study, the stands were intercropped with several traditional crops (Urd, Moong, Wheat), along with aromatic crops (Mentha and Cymbopogon spp.) to obtain maximum production of tree biomass without any detrimental effect on the growth and production of intercrops. The height and dbh at different ages of Eucalyptus tree in sole as well as in intercropped fields are given in Table–1. The trees grown in stands treated with crops, attained better height and diameter

in comparison to sole stands at all the ages (Table –1). It may be due to better care, use of fertilizers, frequent cultural operations and irrigation schedules. Therefore, it has been observed that trees grown under agroforestry attained higher growth as compared to those grown in forest conditions (Singh *et al.*, 1988 and Mohsin, 2015) [35, 25].

Rapid growth of the trees under agroforestry conditions is suggestive of the fact that trees under this system are able to utilize nutrition and cultural operations given to intercrop under them. Soil cultivation is also beneficial to plantations even if no intercrops are grown. Pourtet (1961) [29] has observed that difference in the intensity of cultural methods even in the same plant species alone resulted in growth differences upto 300%. Prevasto and Sekawin (1979) [31], have pointed out that frequent tillage was mus for good growth of trees, even if no intercrops was grown. Similar studies are in conformity to Singh *et al.*, 1985 [34].

The total annual litter production (t/ha/yr) was lower in the pure plantation in comparison to intercropped stands. In the pure stands it ranged between 0.43 to 8.12, while in intercropped stands, it was 0.47 to 8.57 t/ha/yr at various ages of their growth (Table-2). The difference in total litter production in the sole and intercropped stands was not significant. The litter production was lower in the juvenile stands but it increased significantly ($P<0.05$) in the adult ages. This increase in the litter production was due to increase in the number of branches, twigs and leaves of the trees with advancing age of the stands. (Mohsin, 2005 and Mohsin and Singh, 2007) [23, 24].

Though the concentration of nutrients decreased with increasing age of the stands but their total addition to the soil through litterfall was increased significantly ($P<0.01$) with increasing age (Table–3). This was due to significant increase in the total litter production with advancement of the age of the trees in the stands.

The available N,P,K contents (kg/ha) of soil under the pure stands was found to be higher than the soil of the intercropped stands (Table-4). However, most of the P (22-26%) was accumulated in the soil at the depth of 15-30 cm. This was due to washing effect of the P already available in the upper strata (0-15cm) of the soil and the P added through litterfall. The type of vegetation grown under the tree also reflected soil property (Jaques *et al.*, 1975 and Seth *et al.* 1963) [13, 33]. Therefore the available nutrients were found to be higher in the soil of the stands intercropped with wheat in comparison to Urd and Moong.

Available nutrients were found to be higher in the soil of the stands intercropped with Aromatic grasses in comparison to Mentha, because it extracts nutrient very rapidly from the soil while Aromatic grasses draw it slowly. Similar findings in relation to available nutrients have been reported from different strata of the soil under the Eucalyptus hybrid pure as well as intercropped with Aromatic grasses (Singh *et al.*,1989) [26], Pinus patula (Pal *et al.*,1985) [28], E. globules and Black wattle plantations

(Venkataramanan *et al.*, 1983 [39], Mohsin and BabuRam 2002 [21], Mohsin and Singh, 2003 [22], Mohsin 2005 and Mohsin and Singh, 2007) [23, 24].

The data recorded on the yield of grains (q/ha) and oil yield (kg/ha) has been given in Table –5. It is revealed from the Table that higher grain and oil yield has been recorded in pure fields, than intercropped with Eucalyptus. In Aromatic grasses, oil yield increases upto fourth year, but in fifth year it decreased. (Mohsin and Singh 2007) [24].

The oil yield of Mentha and Aromatic grasses depends upon its herbage, which was recorded under trees was less due to increased amount of shade, in comparison to pure fields. In the study, it was also observed that herb yield was recorded highest in rainy season harvest, continuing by winters and summer harvests. In the study it was also seen that oil percentage of all the Aromatic grasses was low in rainy season harvest. Shorter period of sunshine due to clouds and more shade under trees, resulted in reduction of oil contents. These findings are in conformity with those of Dutt and Thakur, 2004; KariKalan *et al.*2002 [15], Thakur and Dutt, 2007 [38] and Mohsin, 2016 [26].

The input use pattern in Urd, Moong, Wheat, Mentha and Cymbopogon spp. cultivation is clearly indicated in the Table : 6,7,8. It is observed that the cost of cultivation per hectare for crops amounted to Rs. 25325.00 (urd), Rs. 27375.00 (Moong), Rs. 26875.00 (Wheat), Rs. 60512.26 (*M. arvensis*), Rs.61512.26 (*M. piperita*) and Rs. 5,15,000.00 (for each Cymbopogon spp.) and operational costs and fixed costs are individually computed on per hectare basis.

It is revealed from the study that the fixed costs in Mentha production constituted 41.23% of the total cost. The major cost under fixed cost was rental value of owned land which constituted around 37.84% of the total cost of cultivation. It is clear from the analysis that the operational cost is the major cost in Mentha production is mainly due to high cost of labour and irrigation. The analysis of cost and return structure revealed that Mentha production was profitable in the study area.

Urd, Moong and Wheat production was 12.5 & 11.2, 10.9 and 52.4 & 53.2 q/ha, respectively and its average price was Rs. 3300.00 & Rs.4300.00 (Urd), Rs.4850.00 (Moong) and Rs.1285.00 & Rs. 1400.00 (Wheat) per quintal.

Mentha arvensis and *Mentha piperita* oil production in the study area was 190.4 and 104.2 kg/ha, respectively and the average price of oil was Rs. 1200.00 and Rs.2400.00 per Kg, respectively, in the particular year of the study.

In the last five years of study, Cymbopogon spp. oil production per hectare was 1049.3 kg (*C. winterianus*), 860.3 kg (*C. martinii*) and 1166.6 kg (*C. flexouses*) and it is revealed that during the particular years of study. The average price of oil was Rs.900.00 (*C. winterianus*), Rs.1500.00 (*C. martinii*) and Rs.800.00 per Kg. (*C. flexouses*) in isolated fields of crop and Gross Return and Net Profit of each crop is also shown in Table – 10.

Total Production of Eucalyptus wood was 4555.5 qtl./ha ; in which 1548.25 qtl. (Bali: 50% thinning at the age of 5 years), 1786.0 qtl. (Over size), 526.0 qtl. (Under size), 511.0 qtl. (Sokta) and 325.0 qtl. (Fuel wod), during the 8 years of study.

Production of Eucalyptus wood was 4555.5 q/ha and its average price was Rs.450.00 per quintal of Bali, Rs. 625.00, Rs. 550.00, Rs. 480.00 and Rs.375.00 per quintal; for over size, under size, sokta and fuel wood, respectively. Cost of cultivation (Table 9- A & B & Table 10) of Eucalyptus is Rs. 4,11,745.00 per hectare. After 8 years average Gross Return from Eucalyptus wood was Rs. 2469417.00 per hectare only; whereas its Net Profit was seen upto Rs.2057672.00 per hectare only.

If we reveal the study of Eucalyptus intercropped with crops, it is seen that, after 8 years of study, the Gross Return was Rs. 5378228.00 only, while the Net Profit was Rs.3163385.24 per hectare only.

The major constraints faced by Mentha growers was lack of support price system (Table – 12).

As evident from the results on root biomass (Table- 13) the age of the trees had significant effect on the total root system

of Eucalyptus trees. The total root biomass is also given in Table, at various age groups in gm/tree.

Similar results have been reported by (Mc Minu, 1963) [19] for Douglas fir; Ruark and Bockheim (1987) [32] and Mohsin *et al.* (2020) 27[] for Populus tremuloides and Populus deltoids, respectively.

Regarding the radial distribution of the roots, the results indicated that in all the age group of trees the total root biomass decreased continuously with increasing radial distance from the tree base at all the soil depths. The results indicated that as the age of trees increased, the radial span of roots also increases. Regarding, the vertical distribution of the roots of the Eucalyptus, the results indicated that the total root biomass decreased continuously with increasing soil depth at all the radial distances and under all the ages. According to Zohar (1985) [40], concentration of most roots were reported at a depth of 40-80 cm in Eucalyptus. This indicated that Eucalyptus has superficial root system.

The results further indicated that the major part of the root system of juvenile age groups was made up of medium roots (0.5-1.5); while in old age groups the major part of the root system was made up of thick roots (>1.5cm). It is well known that the trees which develop strong tap roots are capable of penetrating the soil to greater depths for anchorage and moisture; so Eucalyptus survives well on relatively dry sites.

Table 1: Dbh (cm) and height (m) of Eucalyptus hybrid as affected by age and treatments

Treatments/Age(Yrs)	Dbh (cm)								Height (m)							
	1 2012	2 2013	3 2014	4 2015	5 2016	6 2017	7 2018	8 2019	1 2012	2 2013	3 2014	4 2015	5 2016	6 2017	7 2018	8 2019
Eucalyptus – Sole	1.2	2.5	6.6	10.5	13.1	14.0	14.5	14.9	2.8	6.2	9.8	13.9	17.1	20.3	21.6	23.8
Eucalyptus+Black gram –PU 31	-	3.6	-	-	-	-	-	-	-	6.6	-	-	-	-	-	
Eucalyptus+Moong bean-Pant moong 5	1.8	-	-	-	-	-	-	-	3.1	-	-	-	-	-	-	-
Eucalyptus+Wheat-HD-2967	2.1	-	-	-	-	-	-	-	3.4	-	-	-	-	-	-	-
Eucalyptus+Menthaarvensis- Kosi	-	5.4	-	-	-	-	-	-	-	8.6	-	-	-	-	-	-
Eucalyptus+Menthapiperita- Kukrail	-	5.2	-	-	-	-	-	-	-	8.5	-	-	-	-	-	-
Eucalyptus+Cy.winterianus-Mandakni	-	-	8.2	12.1	14.5	15.2	19.5	20.1	-	-	11.0	14.7	19.2	22.5	25.5	27.6
Eucalyptus+Cy.martinii-PRC-1	-	-	8.8	12.9	15.7	16.6	20.4	20.9	-	-	11.5	15.5	20.1	23.2	26.6	29.4
Eucalyptus+Cy.flexouoses-Krishna	-	-	8.5	12.5	14.8	16.1	19.9	20.4	-	-	11.2	15.1	19.6	22.8	25.9	28.2

Table 2: Total litter production (t/ha) in Eucalyptus hybrid as affected by age and treatments

Treatments/Age(Yrs)	Eucalyptus hybrid Age(Years)							
	1 2012	2 2013	3 2014	4 2015	5 2016	6 2017	7 2018	8 2019
Eucalyptus - Sole	0.43	0.68	2.31	3.89	4.98	6.12	7.65	8.12
Eucalyptus+Black gram –PU 31	-	0.74	-	-	-	-	-	-
Eucalyptus+Moong bean-Pant moong 5	0.47	-	-	-	-	-	-	-
Eucalyptus+Wheat-HD-2967	0.52	-	-	-	-	-	-	-
Eucalyptus+Menthaarvensis- Kosi	-	0.89	-	-	-	-	-	-
Eucalyptus+Menthapiperita- Kukrail	-	0.92	-	-	-	-	-	-
Eucalyptus+Cy.winterianus-Mandakni	-	-	2.58	4.21	5.12	6.68	7.91	7.99
Eucalyptus+Cy.martinii-PRC-1	-	-	2.76	4.46	5.82	6.89	8.35	8.57
Eucalyptus+Cy.flexouoses-Krishna	-	-	2.69	4.35	5.32	6.75	8.16	8.35

Table 3: Total addition of nutrients to the soil through litterfall (Kg/ha/yr) of Eucalyptus hybrid as affected by age and treatments

Treatments/ Age (Yrs)	Eucalyptus hybrid Age(Years)							
	1 2012	2 2013	3 2014	4 2015	5 2016	6 2017	7 2018	8 2019
	N							
Eucalyptus - Sole	4.71	5.74	16.17	24.51	28.61	31.21	32.89	33.41
Eucalyptus+Black gram –PU 31	-	6.43	-	-	-	-	-	-
Eucalyptus+Moong bean-Pant moong 5	5.11	-	-	-	-	-	-	-
Eucalyptus+Wheat-HD-2967	5.50	-	-	-	-	-	-	-
Eucalyptus+Menthaarvensis- Kosi	-	8.21	-	-	-	-	-	-
Eucalyptus+Menthapiperita- Kukrail	-	8.02	-	-	-	-	-	-
Eucalyptus+Cy.winterianus-Mandakni	-	-	22.73	30.50	33.11	39.21	48.51	49.81
Eucalyptus+Cy.martinii-PRC-1	-	-	23.41	31.45	35.61	41.82	51.46	53.44
Eucalyptus+Cy.flexouoses-Krishna	-	-	23.11	30.81	34.34	40.14	49.96	51.62
P								
Eucalyptus - Sole	0.29	0.42	0.96	1.72	2.51	3.28	3.49	3.72
Eucalyptus+Black gram –PU 31	-	0.42	-	-	-	-	-	-
Eucalyptus+Moong bean-Pant moong 5	0.34	-	-	-	-	-	-	-
Eucalyptus+Wheat-HD-2967	0.37	-	-	-	-	-	-	-
Eucalyptus+Menthaarvensis- Kosi	-	0.96	-	-	-	-	-	-
Eucalyptus+Menthapiperita- Kukrail	-	0.84	-	-	-	-	-	-
Eucalyptus+Cy.winterianus-Mandakni	-	-	1.34	1.91	2.92	3.72	4.67	4.91
Eucalyptus+Cy.martinii-PRC-1	-	-	1.57	2.11	3.09	3.89	4.95	5.28
Eucalyptus+Cy.flexouoses-Krishna	-	-	1.56	1.97	2.97	3.77	4.83	5.09
K								

Eucalyptus - Sole	3.98	4.70	13.72	21.42	25.41	27.64	29.93	30.12
Eucalyptus+Black gram –PU 31	-	5.21	-	-	-	-	-	-
Eucalyptus+Moong bean-Pant moong 5	4.15	-	-	-	-	-	-	-
Eucalyptus+Wheat-HD-2967	4.36	-	-	-	-	-	-	-
Eucalyptus+Menthaarvensis- Kosi	-	7.83	-	-	-	-	-	-
Eucalyptus+Menthapiperita- Kukrail	-	7.22	-	-	-	-	-	-
Eucalyptus+Cy.winterianus-Mandakni	-	-	15.64	25.14	27.42	30.50	35.67	38.78
Eucalyptus+Cy.martinii-PRC-1	-	-	16.15	25.61	28.25	31.22	37.43	40.22
Eucalyptus+Cy.flexuosus-Krishna	-	-	15.92	25.20	28.11	30.83	36.83	39.15

Table 4: Nutrient Contents of Soil (Kg/ha) under Eucalyptus hybrid after 8 years duration

Treatments/ Age (Yrs)	N			P			K		
	Depth (cm)								
	0-15	15-30	30-45	0-15	15-30	30-45	0-15	15-30	30-45
Eucalyptus - Sole	432.0	242.0	209.0	28.0	33.0	26.0	300.0	223.0	159.0
Eucalyptus+Black gram –PU 31	405.0	235.0	194.0	24.1	32.0	14.2	291.0	218.6	155.0
Eucalyptus+Moong bean-Pant moong 5	409.0	238.0	196.0	24.9	31.9	14.5	294.0	219.2	156.6
Eucalyptus+Wheat-HD-2967	425.0	237.0	206.0	23.6	30.2	13.8	290.5	219.9	157.8
Eucalyptus+Menthaarvensis- Kosi	371.0	208.0	185.0	22.0	28.0	22.0	282.0	203.0	144.0
Eucalyptus+Menthapiperita- Kukrail	372.5	208.5	186.1	22.5	27.8	22.6	283.6	204.5	145.9
Eucalyptus+Cy.winterianus-Mandakni	392.0	229.0	190.0	28.0	31.0	24.0	288.0	214.0	151.0
Eucalyptus+Cy.martinii-PRC-1	394.0	231.0	189.0	28.7	30.6	23.2	289.5	215.1	152.6
Eucalyptus+Cy.flexouoses-Krishna	393.0	228.0	191.0	28.2	31.4	23.7	289.0	214.5	150.2

Table 5(A):

Crop	Cultivation/Sowing Time	Harvesting Time
Eucalyptus	June last week 2011	Nov.-Dec. 2019
Urd	June 2011	Oct. 2011
Wheat	Nov. 2011	April 2012
Moong	June 2012	Oct. 2012
Mentha	Feb. 2013	May 2013
Urd	June 2013	Oct. 2013
Wheat	Nov. 2013	April 2014
Aromatic grasses	June – 2014	Oct.2014. Feb.2015
		May 2015 Aug.2015 Nov.2015
		Feb. 2016 May 2016 Aug. 2016
		Nov.2016 Feb.2017 May 2017
		Aug. 2017 Nov. 2017 Feb.2018
		May 2018 Aug. 2018 Nov. 2018
Conducted Harvesting Of Eucalyptus Trees		--- Nov- 2019 ----

Table 5: Yield of intercrops per hectare as affected by age and treatments.

Treatments/Age(Yrs)	2011	1 2012	2 2013	3 2014	4 2015	5 2016	6 2017	7 2018	8 2019
Eucalyptus+Black gram –PU 31	9.6 (12.5)	-	8.8 (11.2)	-	-	-	-	-	-
Eucalyptus+Moong bean-Pant moong 5	-	9.8 (10.9)	-	-	-	-	-	-	-
Eucalyptus+Wheat-HD-2967	-	46.6 (52.4)	-	42.5 (53.2)	-	-	-	-	-
Eucalyptus+Menthaarvensis- Kosi	-	-	160.5 (190.4)	-	-	-	-	-	-
Eucalyptus+Menthapiperita- Kukrail	-	-	85.4 (104.2)	-	-	-	-	-	-
Eucalyptus+Cy.winterianus-Mandakni	-	-	-	141.1 (196.2)	148.4 (205.6)	156.9 (212.6)	161.5 (220.5)	158.7 (214.4)	-
Eucalyptus+Cy.martinii-PRC-1	-	-	-	97.6 (155.2)	102.4 (162.6)	114.5 (175.1)	126.3 (189.2)	119.1 (178.2)	-
Eucalyptus+Cy.flexouoses-Krishna	-	-	-	150.4 218.5)	156.2 (222.4)	162.9 (233.3)	168.7 (242.6)	172.5 (249.8)	-

Values in paranthesis are yield of sole crop.
Yield of grains is in q/ha and Oil Yield is in Kg/ha

Table 6: Cultivation Cost and Net Profit of crops (Sole) Rs.per hectare.

Head	Black gram 2011	Black gram 2013	Moong Bean 2012	Wheat 2012	Wheat 2014
Land Preparation	3500.00	3500.00	3500.00	3750.00	3750.00
Seed Rate	1200.00	1200.00	3000.00	4000.00	4000.00
Seed Treatment	625.00	625.00	625.00	875.00	875.00
Sowing	3000.00	3000.00	2250.00	2500.00	2500.00
Fertilizers and Manures	2500.00	2500.00	2000.00	5500.00	5500.00
	2250.00	2250.00	1250.00		
Weeding – 2	4500.00	4500.00	4500.00	3000.00	3000.00
Plant Protection Chemicals	1250.00	1250.00	1250.00	1250.00	1250.00
Miscellaneous	2750.00	2750.00	3000.00	1500.00	1500.00
Harvesting and Threshing	6000.00	6000.00	4500.00	2500.00	2500.00
Transport	1250.00	1250.00	1500.00	2000.00	2000.00
Total Cost (A)	25325.00	25325.00	27375.00	26875.00	26875.00
Total Yield q/hac	12.5	11.2	10.9	52.4	53.2
Price Rs/q	3300.00	4300.00	4850.00	1285.00	1400.00
Gross return Rs/hac (B)	41250.00	48160.00	52865.00	67334.00	74480.00
Net Profit Rs/hac (B-A)	15925.00	22835.00	25490.00	40459.00	47605.00
C : B Ratio	1.63	1.90	1.93	2.51	2.77

Table 7: Cultivation Cost and Net Profit of *Mentha arvensis* and *Mentha piperita*(Sole) Rs./ha.

Head	*Menthaarvensis*	*Menthapiperita*	%
Operational Cost			
Human Labour	13988.20		24.90
Machine Labour	4950.70		8.56
Suckers	2500 @ 5000/q	3500.00 @ 7000.00/q	5.19
Manures and Fertilizers	3840.70		6.64
Plant protection	300.00		9.84
Irrigation	5690.60		0.52
Distillation Cost	3200.00		
Interest on working Capital	2216.99		
TOTAL COST (A)	36687.19	37687.19	58.72
Fixed cost			
Depriciation	1012.15		1.74
Land Revenue	21.35		0.04
Rental values of own land	21875.23		37.84
Interest on fixed capital	916.34		1.57
TOTAL FIXED COST (B)	23825.07	23825.07	41.23
TOTAL COST OF CULTIVATION(A+B)	60512.26	61512.26	100.00
OIL YIELD Kg/hac	190.40	104.20	
Price of Oil Rs./kg	1200.00	2400.00	
Gross Return Rs./hac	228480.00	250080.00	
Net Profit Rs./hac	167967.74	188567.74	
C : B Ratio	3.78	4.07	

Table 8: Cultivation Cost of Aromatic Grasses (Sole) Rs./ha.

Heads	Cymbopogonwinterianus					Cymbopogon martini Cymbopogonflexuouses									
	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018	2014	2015	2016	2017	2018
Land Pre.	**4,000**	-	-	-	-	**4,000**	-	-	-	-	**4,000**	-	-	-	-
Sowing and Transplanting	6,000	-	-	-	-	6,000	-	-	-	-	6,000	-	-	-	-
Weedings	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
Slips @ Rs.5/-	50,000					50,000					50,000				
Irrigation	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
Har.	10,000	15,000	15,000	15,000	15,000	10,000	15,000	15,000	15,000	15,000	10,000	15,000	15,000	15,000	15,000
Oil Ext.	30,000	45,000	45,000	45,000	45,000	30,000	45,000	45,000	45,000	45,000	30,000	45,000	45,000	45,000	45,000
Fert.& Man. & App	10,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Pl.prot chem. & App	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000	8,000
Total Exp.Rs	13,1000.00	96,000.00	96,000.00	96,000.00	96,000.00	13,1000.00	96,000.00	96,000.00	96,000.00	96,000.00	13,1000.00	96,000.00	96,000.00	96,000.00	96,000.00
Oil Kg/ha	196.2	205.1	212.6	220.5	214.4	155.2	162.6	175.1	189.2	178.2	218.5	222.4	233.3	242.6	249.8
Price of Oil Rs./Kg	900	900	900	900	900	1500	1500	1500	1500	1500	800	800	800	800	800

Gross return Rs./ha	1,76,580.00	1,84,590.00	1,91,340.00	1,98,450.00	1,92,960.00	2,32,800.00	2,43,900.00	2,62,650.00	2,83,800.00	2,67,300.00	1,74,800.00	1,77,920.00	18,6,640.00	1,94,080.00	1,99,840.00
Net Profit Rs./ha	4,55,800.00	88,590.00	95,340.00	1,02,450.00	96,960.00	1,01,800.00	1,47,900.00	1,66,650.00	1,87,800.00	1,71,300.00	43,800.00	81,920.00	90,640.00	98,080.00	1,03,840.00
C : B Ratio	1.35	1.92	1.99	2.07	2.01	1.78	2.54	2.74	2.96	2.78	1.33	1.85	1.94	2.02	2.08

Table 9: (A.) Cost of Cultivation Of Eucalyptus hybrid Rs./hac. Spacing : 4mx 2m Number of trees : 1250/ha Survival = 90%

S. No.	Head of Expenditure	Cost (Rs.)
	A. First Year	
1.	Site preparation and alignment	5500.00
2.	Cost of 1250 plants @ Rs.15 per plant	18750
3.	Digging of Pits and Planting cost@ Rs.3 per plant	3750
4.	Cost of insecticides	2000
5.	Cost of 4 weeding @ Rs.1.50 per plant	7500
6.	Cost of 2 harrowing @ Rs.1500 per harrowing	3000
7.	Cost of irrigation (14) @ Rs.750 per irrigation	10500
8.	Cost of Fertilizer	4000
9.	Miscellaneous Cost	3000
	Total Expenditure (A)	58000
	B. Second Year to Eigth Year	
1.	Harrowing per Year (2) @ 1500/harrowing	21000
2.	Cost of 4 weeding per Year for 4 years @ Rs. 1.5/plant	27000
3.	Cost of 3 weeding per Year for 3 years @ Rs. 1.5/plant	12645
4.	100 (14x2, 12x3, 9x2) irrigation @ Rs.750/irrigation	61500
5.	Fertilizers for 7 years @ Rs.4000/year	28000
6.	Miscellaneous cost @ Rs.3000/year	21000
7.	Felling and Loading Cost @ Rs. 50/qtl.	182600
	TOTAL EXPENDITURE (B)	353745
	Grand Total (A + B) 58000 + 353745 =	411745

Table 9: (B.) Eucalyptus: Return per hectare Bali: 563 trees. No. of Final trees harvested: 562. Average Yield: 6. 5 qtl/tree.

S. No.	Category of size	Quantity (qtl.)	Rate/qtl. At felling site (Rs.)	Total Aount (Rs.)
1.	Bali (50% thinning at age of 5 years)	1548.25	450.0	696712.00
2.	Over Size	1786.0	625.0	1116250.00
3.	Under Size	526.0	550.0	289300.00
4.	Sokta	511.0	480.0	245280.00
5.	Fuelwood	325.0	375.0	121875.00
	Grand Total	4555.5		
	Total Return (Gross Return)			2469417.00
	Total Expenditure			411745.00
	Net Return			2057672.00
	Net Return per year			257209.00
	C : B Ratio			5.99

Table 10: Economic analysis of Eucalyptus hybrid (Sole) and Crops (Sole) Rs./ha

Crops	Cost of Cult./ha	Yield/ha	Price (Rs.)	Gross Return Rs./ha	Net Profit Rs./ha	C : B Ratio
	411745			2469417.00	2057672.00	5.99
Black gram –PU 31	25325	12.5 qtl.	3,300/qtl.	41250	15925.00	1.63
	25325	11.2 qtl.	3,300/qtl.	48160	22835.00	1.90
Moong bean-Pant moong 5	27375	10.9 qtl.	4,850/qtl.	52865	25490.00	1.93
Wheat-HD-2967	26875	52.4 qtl.	1,285/qtl.	67,334	40,459.00	2.51
Menthaarvensis- Kosi	60512.26	190.4 Kg.	1,200/Kg.	22,8,480	1,67,967.00	3.78
Menthapiperita- Kukrail	61512.26	104.2 Kg.	2,400/Kg.	25,0,080	1,88,567.00	4.07
Wheat-HD-2967	26875	53.2 qtl.	1,400/qtl.	74,480	47,605.00	2.77
Cy.winterianus-Mandakni	515000	1049.3 Kg.	900/Kg.	94,4,370	4,29,370.00	1.83
Cy.martinii-PRC-1	515000	860.3 Kg.	1,500/Kg.	12,90,450	7,75,450.00	2.51
Cy.flexouoses-Krishna	515000	1166.6 Kg.	800/Kg.	9,33,280	4,18,280.00	1.81

Price of Product is mentioned in the particular year it is harvested

Table 11: Economic analysis of Eucalyptus hybrid based AgroForestrySystem Rs./ha.

Treatments	Cost of Cultivation	Yield/ha	Price (Rs.)	Gross Return (Rs.)	Net Profit (Rs.)	C : B Ratio
Eucalyptus+Black gram –PU 31	411745 25,325 25,325	9.6 qtl. 8.8 qtl.	3,300.00/q 4,300.00/q	2469417 35,640.00 46,440.00	2057672.00 10,315.00 21,115.00	5.99 1.41 1.83
Eucalyptus+Moong bean-Pant moong 5	30,800	9.8 qtl.	4,850.00/q	50,440.00	19,640.00	1.64
Eucalyptus+Wheat-HD-2967	27,747.50	46.6 qtl.	1,285.00/q	59881.00	32133.50	2.16
Eucalyptus+Menthaarvensis- Kosi	60,512.26	160.5 Kg.	1,200.00/Kg	2,28,480.00	1,67,967.00	3.78
Eucalyptus+Menthapiperita- Kukrail	61,512.26	85.4 Kg.	2,400.00/Kg	2,50,080	1,88,567.74	4.07
Eucalyptus + Wheat HD- 2967	26,875.00	42.5 qtl.	1,400.00/q	59,500.00	32,625.00	2.21
Eucalyptus+Cy.winterianus-Mandakni	5,15,000.00	766.6 Kg.	900.00/Kg	6,89,940.00	1,74,940.00	1.34
Eucalyptus+Cy.martinii-PRC-1	5,15,000.00	559.90 Kg.	1,500.00/Kg	8,39,850.00	3,24,850.00	1.63
Eucalyptus+Cy.flexouoses-Krishna	5,15,000.00	810.7 Kg.	800.00/Kg	6,48,560.00	1,33,560.00	1.26
	2214842.02		Total	53,78,228	31,63,385.24 31,63,400.00	

Table 12: Major Constraints faced by Mentha growers in Study area

Heads	No. of Beneficiaries	%	Rank
Lack of training on cultivation methods	54	90.0	II
Climate Change	52	86.7	V
Electric Problem	50	83.3	VIII
High Input Costs	48	80.0	X
Attack by Pests and Diseases	49	81.67	IX
Lack of trained labour for cultivation	51	85.0	VI
Lack of Support price system	55	91.7	I
Inadequate Market Information	46	76.7	XII
Lack of Improved and Quality distillation Unit	51	85.0	VII
High Cost of good quality distillation Unit	54	90.0	III
High Processing Cost	52	86.7	IV
Lack of awareness about export market	47	78.3	XI

Table 13: Dry Root Biomass (gm/tree) of E. hybrid trees under different age groups, radial distances, soil depths and root grades

Variables	Age (years)						
	2	3	4	5	6	7	8
Radial Distances (cm) 0-50	881.2 (62.13)	3232.7 (62.74)	4832.4 (59.57)	6995.1 (54.18)	8635.8 (44.26)	10571.9 (43.13)	12678.1 (46.08)
50-100	361.8 (25.51)	1245.5 (24.17)	2454.2 (30.25)	4561.1 (35.33)	6060.6 (31.06)	7649.7 (31.20)	8778.2 (31.91)
100-150	175.3 (12.36)	674.6 (13.09)	1246.7 (15.37)	2315.1 (17.93)	4812.5 (24.67)	6289.0 (25.65)	7550.1 (27.44)
Soil Depth (cm) 0-15 d1	921.8 (64.99)	3171.7 (61.55)	4972.1 (61.30)	6556.5 (50.79)	8622.9 (44.20)	10946.4 (44.66)	12674.2 (46.07)
15-45 d2	397.1 (28.00)	1396.5 (27.10)	2015.4 (24.84)	3694.6 (28.62)	5159.2 (26.45)	6362.0 (25.96)	7862.2 (28.58)
45-75 d3	91.7 (6.47)	420.8 (8.17)	1245.5 (15.35)	2058.9 (15.94)	3483.5 (17.86)	4383.2 (17.88)	5351.1 (19.45)
75-105 d4	7.7 (0.54)	163.8 (3.18)	892.5 (11.00)	1252.5 (9.70)	2243.3 (11.49)	2819.0 (11.50)	3250.6 (11.81)
Root Grades Fibrous g1	45.4 (3.20)	169.6 (3.29)	202.5 (2.49)	271.1 (2.10)	301.1 (1.54)	368.7 (1.50)	418.5 (1.52)
Thin g2	101.4 (7.15)	372.8 (7.29)	465.1 (5.73)	531.2 (4.11)	638.0 (3.27)	769.6 (3.13)	815.6 (2.96)
Medium g3	688.9 (48.57)	2556.7 (49.62)	2891.5 (35.64)	3160.1 (24.48)	3259.1 (16.70)	3887.7 (15.86)	4112.1 (14.94)
Thick g4	582.6 (41.08)	2053.7 (39.86)	4551.7 (56.11)	8956.1 (69.38)	15310.7 (78.48)	19484.6 (79.49)	22161.1 (80.56)
Total (gm/tree)	1418.3 (100)	5152.8 (100)	8110.8 (100)	12908.5 (100)	19508.9 (100)	24510.6 (100)	27507.3 (100)

Values in paranthesis indicate the percentage of total root biomass

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