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POTENTIAL OF EUCALYPTUS CAMALDULENSIS FOR AGRO FORESTRY AND ENERGY PLANTATION ON PROBLEM SOILS

Nasim I. Butt*, Amer Saleem, Sarwat N. Mirza, Muhammad Haneef
Department of Range, Wildlife and Forestry Management, PMAS Arid Agriculture University Rawalpindi, Pakistan.

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ABSTRACT

Pakistan is facing energy and water crisis, and on the other hand, the prominent acreage of land is unsuitable for the cultivation of crops because of salinity and waterlogging. Thus, eucalyptus could be the most suited option in those soils which are currently unused. This study was conducted in Mochiwala plantation (Chak 178/JB) having normal soil and Shorkot irrigated forest plantation having saline and water-logged soil situated in district Jhang. The major objectives of study were to explore the potential of eucalyptus species for agroforestry and energy plantation on problem soils. For study-II, successive surveys were conducted to collect data from the farmers regarding agro-forestry potential of eucalyptus. Whereas, calorific values of the wood samples were calculated through the bomb cylinder and bucket technique. Further, the thermal properties of the wood samples were also examined. The findings indicated that Eucalyptus (Eucalyptus camaldulensis), Farash (Tamarix aphylla), Kikar (Vachellia nilotica) and Shisham (Dalbergia sissoo) were the dominating species cultivated by the farmers for agroforestry purposes. About 72.5% of respondents had the cultivation of these trees around the boundary of their land. Agro-forestry was significantly contributing economically to the farmers as they were getting Rs. 40000/- to Rs. 50000/- per annum from these trees in addition to major crops i.e., rice, Moong, Wheat and Corn. The highest calorific value of Eucalyptus camaldulensis is reported as 4900 K. cal/gm in normal soil, 4909 K. cal/gm in treated saline soil and 4750 K. cal/gm in treated water-logged soil. This implies that treated saline and treated waterlogged soils have strong potential for energy plantations.

Corresponding Author: Nasim I. Butt
Email: pa.dfokhushab@gmail.com

INTRODUCTION

Eucalyptus is considered the most diverse and biggest of tree genera. At present, it is being widely cultivated in plantation in many countries of the world for pulp production particularly (Doughty, 2000). It is also one of the most bio-economic plant species having a vigorous potential to grow on problematic soils including salt affected soils under arid climate (Bennett *et al.*, 2009).

The genus is also planted for a variety of other land protection purposes, including salinity control, in many other countries. Within Australia, there has been substantial recent expansion of eucalypt plantations, concentrated mainly in medium to high rainfall regions (>700 mm annual rainfall). A more sprinkled development of small-scale plantations for remediation of environmental problems has increased the overall tree cover in lower rainfall areas (400–700 mm per year). Dry-land salinity already has affected more than four million hectares of formerly productive agricultural land in mid to low-rainfall regions (Cullen, 2003; Peck and Hatton, 2003).

Eucalypts (Eucalyptus spp.) is one of the most bio-economical plant species, with high potential to grow in salt-affected soil with arid climatic conditions (Bennett *et al.*, 2009). Saline soil reclamation by using eucalypt trees has been well established in many areas of the world and involves strategies such as saline groundwater uptake, heavy rain water absorption, rapid transpiration, generation of chelating organic matter, and prevention of expanding salination by vegetation shading (Feikema *et al.*, 2010; Kawarasaki *et al.*, 2010).

Salinity imposes direct economic costs through reduced crop yields. In Pakistan, salinity is one of the country's most serious environmental problems, caused by human-induced long-term mismanagement of irrigation. Of the 25% of irrigated land affected by salinity, approximately 1.4 million hectares of all agricultural land has now been abandoned (World Bank, 2006). The total annual cost of crop losses from salinity in Pakistan has been estimated to range from 15 to 55 billion rupees (Rs) (A$340 million to A $1.2 billion) per year. This is in addition to the Rs.15billion (A$340 million) estimated to have been lost from the land that has been rendered unproductive. Taking the average cost of reduced yields as Rs. 35billion (A$790 million) per year, the costs of salinity in Pakistan were equivalent to 0.6% of gross domestic production in 2004 (World Bank, 2006). There is only about 11% arable area on the land surface and about one fifth of it is irrigated. Currently, water logging and salinization are threatening many areas of the world, particularly arid areas using artificial irrigation. In India, Pakistan, China, Australia etc. distribution of rainfall is irregular and uncertain. In all such countries irrigation for farming is needed.

In the renewable intensive global energy scenario (RIGES), the majority of biomass energy supplies come from dedicated, high yielding energy plantations. However, in order to satisfy the biomass energy demand of the country by 2014, 6% of the total functional land area would have to be put under Eucalyptus plantations (Kidanu *et al.*, 2005) entailing a major shift in land use. Increasing plantations would create competition between agricultural food crops and Eucalyptus trees for land area, major resources (water and soil nutrients) and light etc.

In countries like Pakistan, where there is extremely low level of forest cover the demand for biomass fuels could exceed the rate of production of biomass in the existing forest. It is necessary to consider whether it is appropriate to use forest and agricultural land for biomass production. If this is required, purposely grown energy crops can become an attractive option as high yields of biomass which can be produced in short time. Jhang city is situated on the left bank of the river Chenab at a distance of about 11 Kilometers from its bed. It lies between north latitude 31º-15‟ and 31º-17‟ and east longitude 72º-18‟ and 72º -22‟ railway line connecting ShorKot Cantt with Sargodha Passes through the Town. Jhang City is situated about 40km from Gojra and Toba Tek Singh cities, Faisalabad city is about 76 km and Chiniot is about 86km from Jhang. In the current changing climatic conditions, it's direly needed to identify tree species which are resistant to harsh climatic and soil conditions. It is also needed to utilize problem soils of the country to enhance forest cover and fulfill the demands of exploding population. Keeping in mind the above-mentioned scenarios current study aimed to assess the potential of Eucalyptus species for agro forestry and energy plantation on saline and waterlogged soils.

METHODOLOGY

This study was conducted in Mochiwala plantation (Chak 178/JB) and Shorkot irrigated forest plantation situated in district Jhang*. According to the report of Soil and Water Testing Labortary Jhang (2017), the soil of Mochiwala plantation (Chak 178/JB) was normal soil whereas Shorkot irrigated forest plantation situated in district Jhang had saline and water-logged soil.

Nursery Raising

In order to raise a nursery of Eucalyptus, the sowing of E. camaldulensis seeds was done in the polythene bags of 4″ × 8″ size and afterwards transplanted in the field area when they attained height of one foot. The use of vigorous healthy planting stock for field planting was ensured.

Area of Block and experimental unit

For the experiment, total 3 blocks were designed and each block comprised over nine kanal area. Each block of 9 kanals was further subdivided into two equal blocks of 4.5 kanals in case of saline and water-logged soil which were further subdivided into three sub plots of 1.5

kanals in each case (i.e. in case of saline and water logged soils) for 3 replications. Nine kanals in case of normal soil were subdivided into three kanals per plot for three replications.

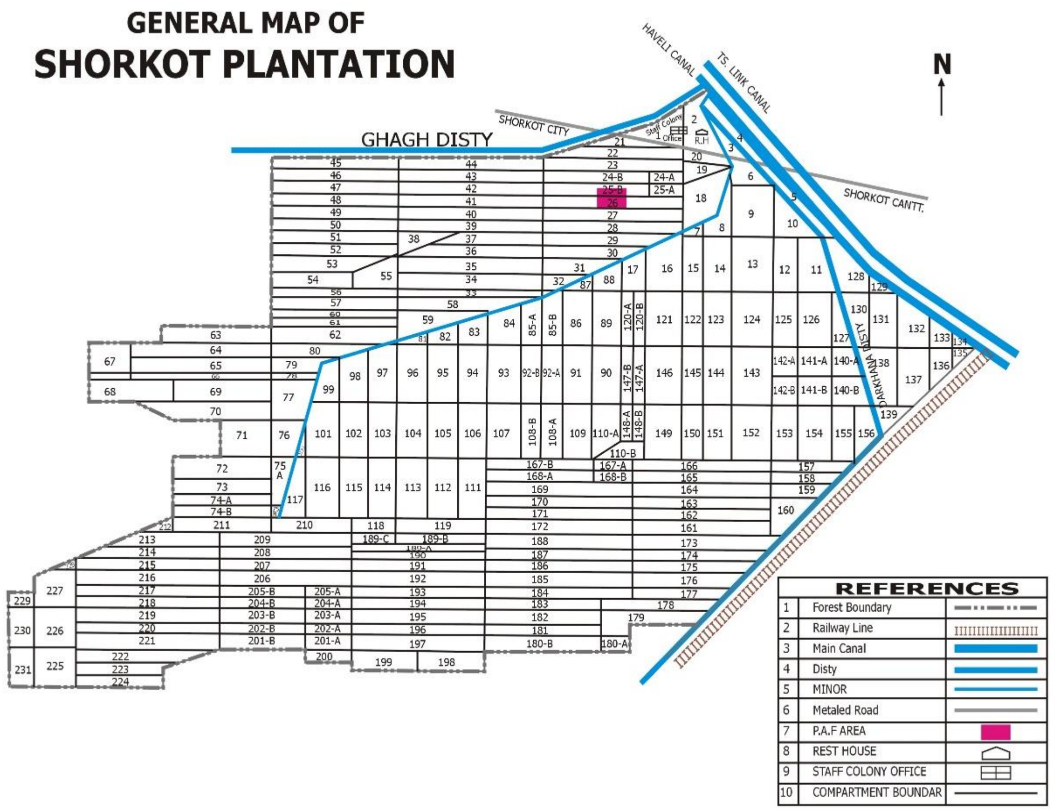

Figure 1. Map of Shorkot Plantation.

Planting geometry

The planting of eucalyptus was done at 10 x 6 feet spacing (where line to line distance was ten feet and plant to plant distance was six feet).

Planting was carried out in the field area of different soils as elaborated below;

Normal Soil

Planting was done on flood irrigation pattern in the study area after jungle clearance, Kana onsequit stubbing, debris collection and burning, ploughing and levelling, layout and management, earth work and layout for proper irrigation system (i.e., making of khalas/mains, passel, trenches, and slots etc.), at 10` x 6`spacing (i.e., 10` line to line and 6`plant to plant distance). Vigorous healthy plantings stock with one foot height was transplanted to field/experimental area.

Proper irrigation @ 02 irrigation/ month were given to the transplanted seedlings with resubbing of kana mesquit uprooting of wild weeds, reopening of khals, bassels, trenches and slots restocking of failed slots with plants afterwards in the subsequent years.

Size of main $= \frac{4`+3`}{2}$ X 2

Size of khal $= \frac{3`+2`}{2}$ X 2

Size of Passel $= \frac{15"+12"}{2}$ X 12"

Size of trench $= \frac{12"+9"}{2}$ X 9"

Size of slot = 12"+12" x 12"

Widhth of cross wood = 10"

Treated Saline Soils

In saline soils following treatments were applied to get vigorous growth of the crops planted in such soils; Flooding with sweet/canal water (if available) for six months at the rate of twice each month to the saline areas before planting in order to increase fertility level and add nutrients, dissolved in canal water. Deep ploughing up to 2`-3` depth was carried out two to three times preferably with chisel plough to loosen the compaction of soil and increase perforation of the soil.

Fine/laser levelling of the area was carried out for uniform supply of irrigation water in desired quantity.

At least 20 bags of gypsum per acre were added to the soil to lower the salinity level and maintain an appropriate level best for vigorous/normal growth of crop.

One gallon of humus/humic acid was applied per acre per year to enhance the microbial growth and activity, increase water absorption, aeration of soil and decrease the density of soil. This process enhanced root growth and fulfilled the requirements of nutrients required for proper growth of the seedlings.

Saline soil without treatment

To grow crop in the saline soil without treatment same method was used as discussed in normal soil.

Water logged soil without treatment

To grow crop in the water-logged soil without treatment same method was used as discussed in normal soil.

Water logged soil with treatment

In water logged soils following treatments were applied to get good results of plants growth.

Mound planting technique, ridge planting technique or modified earthen band technique were used to overcome the problem of water logging which badly affected the growth potential of plants.

The size of mound, ridge or band may be adopted as per site conditions.

The basic is to provide water logging free environment to the growing plants, therefore, height of mound, ridge or bund was kept consistent with depth of stagnant water.

The length of mount was usually 1 meter or less but it was adopted as per site and spacing of plantation to be carried out.

Most important was to use fertile soil with adequate nutrients and drainage capacity.

Experimental design

A widely used experimental design known as Randomized Complete Block Design (RCBD) with three replications was adopted for this study. All silvicultural operations were carried out as per standards and according to the requirement. Number of leaves, plant height, plant diameter and survival% were measured at the interval of one month regularly.

In this study, following parameters were measured

(a) Agro-forestry potential
(b) Energy plantation potential

(a) Agro-forestry Potential

In order to explore the agro-forestry potential, successive surveys with the farmers were conducted. Questionnaire was prepared defining the agro forestry objective and data were collected from the forty farmers through face-to-face interview technique. Before final data collection questionnaire was pretested and amendments in questionnaire were made in accordance with the obtained findings from the pre-testing survey. Data collected were analyzed using excel sheet. Frequency, percentage, mean values and standard deviations were calculated.

(b) Energy plantation potential

Method

For the measurement of calorific/heat value, the saw dust of fifteen hardwoods samples were oven dried and one gram weight of the sample of each wood type was used in oxygen bomb calorimeter for mearing the heat of combustion of samples.

The bomb cylinder and bucket were mounted in the caloric meter. The bomb was completely surrounded by a bucket chamber, sealed co-axially with the bomb head.

After the bomb and bucket were closed and sealed, the bomb was filled with oxygen, the bucket chamber was filled with water, initially equilibrium was established, the bomb was fired and the temperature rise was monitored and recorded under all automatic microprocessor control. Then, at the completion of the test, automatic control releases the residual pressure in the bomb, rinsed the bomb to cool the system and cleared the bucket.

Thermal Properties

Calorific Value

The calorific value of dried powdered wood samples was determined with a bomb calorimeter, in which about 0.5 g of oven-dried wood was completely combusted under a pressure of 425 psi with pure oxygen, and the rise in temperature of the cylinder allowed the calculation of the calorific value when the exact weight of the sample was known. The bomb calorimeter calibrated against benzoic acid standards before the analysis of samples.

Ash Deformation Temperature and Ash Fusion

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Temperature

The deformation and fusion temperature of ash was checked using muffle furnace. The ash was made to cone and kept in muffle furnace and fusion temperature was checked.

Fuel wood value index (FVI)

Fuel wood value index is calculated based on the properties of calorific value, wood density and ash content.

$$\text{Fuel Wood Value Index} = \frac{\text{Calorific value} - \text{Wood Densty}}{\text{Ash content (\%)}}$$

RESULTS AND DISCUSSION

Agro-Forestry and Energy potential

Agro-Forestry potential

Table 1 shows that out of the total 40 respondents, 15% were large scale farmers. Among respondents, 32.5% were medium and more than half (52.5%) of respondents were small scale farmers. This implies that major chunk of farmers were having small landholdings. In this case, agroforestry seems to have great worth for the small scale farmers. Table 1 further indicates that of the total respondents, 85% had size of land between 1-12.5 acres. This is an endorsement that majority of farmers had under 12.5 acres land and were small landholders. Among total respondents, 12.5% were having land size from 12.5 to 25 acres whereas 2.5% of respondents had very large land holdings (more than 25 acres). Data mentioned in Table 1 indicates that, 85% of respondents were owner of their lands followed by 5% respondenst who were owner-cum-tenants and 10% tenants. This implies that the majority of the respondents were owners of their lands and they could make decisions to adopt agroforestry and harvest the benefits of cultivating trees.

Table 1. Farmer category.

Attributes	Frequency (%)
Farmer category	
Large	6 (15)
Medium	13 (32.5)
Small	21 (52.5)
Size of farm in acres	
1-12.5	34 (85)
12.5-25	5 (12.5)
> 25	1 (2.5)
Land tenure status	
Owner	34 (85)
Owner-cum-tenants	2 (5)
Tenant	4 (10)

Table 2. No. of trees on farm.

No. of Trees on farm	Frequency (%)	Mean± SD
1-50	18 (45)	
51-100	15 (37.5)	
101-150	1 (2.5)	126.97±314.40
151-200	2 (5)	
> 200	4 (10)	
No. of tress per acre		
1-10	18 (45)	
11-20	15 (37.5)	13.34±16.79
21-30	1 (2.5)	
31-40	2 (5)	
> 40	4 (10)	

Table 2 shows the number of trees that the each farmer has grown on the land he possessed. Of the total respondents, 45% had less than 50 trees on their farm land. Whereas, 37.5% of respondents had 51-100 trees. Data further indicates that 2.5% of respondents cliamed to have 101-150 tress and 5% respondents reported to have 151-200 trees. One in ten respondents (10%) had more than 200 tress. Perhaps, these farmers were the large landholders. The average trees on on a farmlands in the studya area were 126.97. Table 2 indicates that, 45% of respondents had 1-10 trees in one acre. Moreover, 37.5% of respondents had 11-20 trees in one acre. Among respondents, 2.5 and 5% of respondents had 21-30 and 31-40 trees in one acre, respectivly. One in ten respondent (10%) had more than 40 trees per acre. Statitics further indciated that minimum tree in ince acre was 2.25 and maximum trees were 83. The average trees/acre in the study area were 13.34.

Table 3. Agroforestry practices adopted by farmers.

Agroforestry Practice	Frequency (%)
Blocks/Compact, Boundary	1 (2.5)
Boundary	29 (72.5)
Boundary, Compact	3 (7.5)
Boundary, Scattered	2 (5)
Compact, Scattered	1 (2.5)
Compact, Scattered, Boundary	1 (2.5)
Scattered	3 (7.5)
Total	40 (100)

Data given in Table 3 indicates that 72.5% of respondents had adopted the agroforestry practice cultivation of trees on farm boundary. This type of cultivation was not only generating adiitional capital for the farmers livelihoods but also was serving as wind breakers. Of the total respondents, cultivation of trees on boundary, compact and scattered farm were reported by 7.5 and 7.5% of respondents, respectivly. The adoption of other practices under agroforestry such as compact, scattered, boundary, were adopted by very samll percentage of farmers.

Data mentioned in Table 4 indicate that among different specied cultivated by the farmers, Eucalyptous was the dominant above all others. More than half of respodents (52.5%) had cultivation of Eucalyptous followed by 32.5% who reported to have cultivation of Kikar. Of the total respondents, only 5% had cultivation of Farash and one in ten respondent (10%) had cultivation of shisham.

Table 4. Dominant scpecies.

Species	Frequency (%)
Eucalyptus	21 (52.5)
Farash	2 (5)
Kikar	13 (32.5)
Shisham	4 (10)
Total	40 (100)

Figure 2 indicates that rice, wheat, moong and corn were the prominentc rop being cultivated in the study area by the farmers alongwith agroforestry. Of the total respondents, 55% reported cultivation of rice. This implies that rice was the major crop in the study area. Among other crops, 20, 15, and 10% of respondnets had cultivation of wheat, moong and corn, respctivley. Table 5 shows that farmers were earning on average 45000-60,000 PKR from the rice crop. Farmers further reported that they were earning 20,000-25000, 25000-30,000 and 15000-20,000 PKR from moong, wheat and corn. As for as farm trees were concerned, from the cultivation of eucalytous, kikar, shesham and farash, farmers were earning 40,000-50,000 annual income other than the crops. Findings are more or less endorssed by the Hardiyanti *et al.* (2021) as they found that farmers were earning Rp. 18,831,743.743/year through agroforestry in Indonesia (Hardiyanti *et al.*, 2021). In a recent study, Zada *et al.* (2022) found a statistically significant association between the agro-forestry and economic development. They found that financial capital was increased through the agroforestry. In a study, Kassie (2017) identified through the focus group discussion that agricultural extension agents, natural resource conservation experts and farmers had an agreement that agroforestry had better return to the farmers. Apart from the financial enefits, farmers were getting fire

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woods and attaining livetsock feed from such tree species like kikar and siris.. Moreover, Farash and Eucalyptus were helping farmers in soil reclamation besides producing timber and firewood.

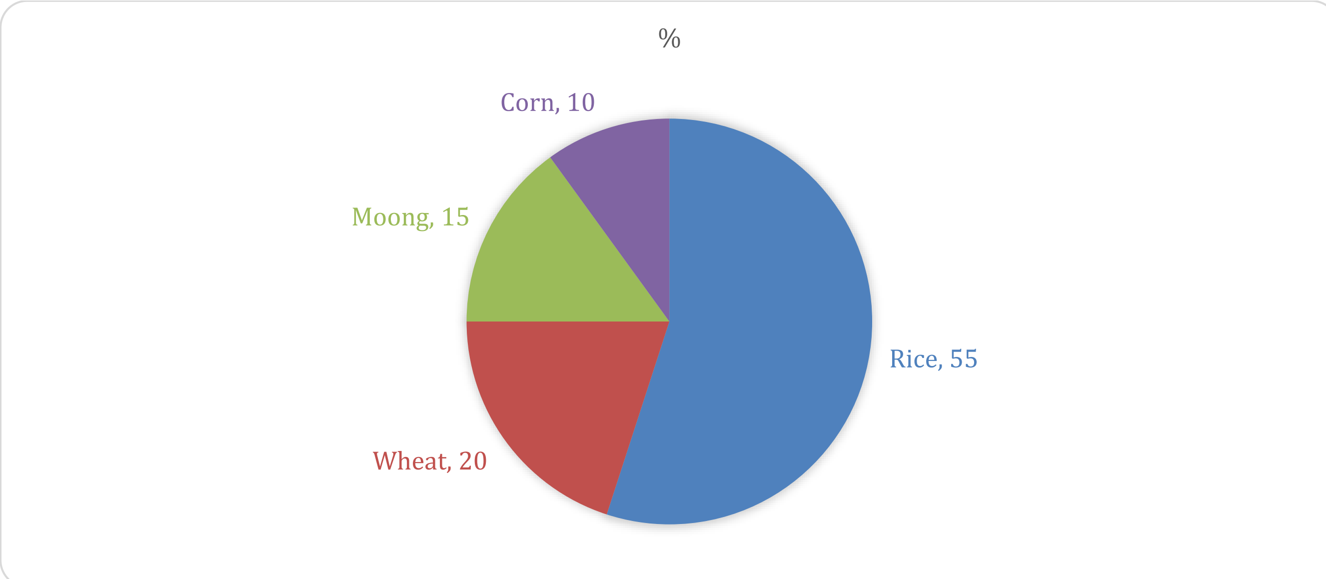

Figure 2. Major crops sown by farmers along with agroforestry.

Table 5. Economic return from agroforestry.

From Crops Sown	Average income of farmers/per acre
Rice*	45000-60000 PKR
Moong	20000-25000 PKR
Wheat	25000-30000 PKR
Corn	15000-20000 PKR
From Trees	
Eucalyptus, Kikar, Shesham, Farash etc	40000-50000 PKR annually
Other Benefits	
Fire wood	
Livestock feed such as Kikar and Sirs	
Farash and Eucalyptus are helping in soil reclamation	
Farash is helping farmers ad Fire Barrier	

Energy potential

Energy potential in key element regarding importance of eucalyptus. Various methods i.e., empirical method and calorimetric method was adopted to compare the calorific values of samples of eucalyptus cultivated under normal soil, saline soil and waterlogged soil. Calorific values were found similar (4900 k cal/kg) under normal soil through both the methods but empirical method (4909 k cal/kg) value was higher than calorimetric method (4900 k cal/kg) under saline soils (Table 6). In case of water-logged soil, empirical method produced higher calorific value (4757 k cal/kg) than calorimetric method which was 4750 k cal/kg (Table 6). Cavalett *et al.* (2018) agreed with the energy potential of eucalyptus and found that 2.5 EJ of electricity or 5 EJ of transportation biofuels were likely to be produced in Brazil from large scale plantation of eucalyptus. The comparison of calorific values of empirical method and calorimetric method is also presented in Table 7. Significant difference was not observed regarding percentage increase or decrease in calorific values of empirical method and calorimetric method.

Table 6. Comparison of calorific values of two methods (K. cal/ Kg) Eucalyptus camaldulensis wood collected from the various soil types (i.e. normal soil, saline soil and water logged soil).

Wood sample	Soil Type	Calorific value (K. cal/Kg)	
		Empirical method	Calorimetric method
Eucalyptus camaldulensis	Normal soil	4900	4900
	Saline soil	4909	4900
	Water logged soil	4757	4750

Table 7. Comparison of heat values of two methods (K. cal/ Kg) Eucalyptus camaldulensis wood collected from the various soil types (i.e. normal soil, saline soil and water logged soil).

Wood sample	Soil type	Calorific value (K. cal/g)		Reported	Percentage difference (%)
		Calculated			
		Empirical method	Calorimetric method		Nil
Eucalyptus camaldulensis	Normal soil	4900	4900	4900	-
	Saline soil	4909	4900	-	-
	Water logged soil	4757	4750		-

Comparison of heat vales of various wood species was also evaluated according to empirical method and calorimetric method with samples of eucalyptus (Table 8). Acacia modesta showed maximum heat values of 4912 BTU/lb by empirical method and 4900 by calorimetric method. Minimum heat value of Tamarix aphylla was noted by empirical methods and it was high under calorimetric method (4835). Eucalyptus produced 4900 by both the methods. In case of water-logged soil, empirical method produced higher calorific value (4757 K cal/kg) than calorimetric method which was 4750 k cal/kg (Table 6). The percentage increase or decrease is also presented in Table 9. Significant difference was not observed regarding percentage increase or decrease in heat values of empirical method and calorimetric method of various species (Table 9).

Table 8. Comparison of heat values of different wood species with Eucalyptus camaldulensis.

Wood samples	Calorific value (BTU/lb)	
	Empirical method	Calorimetric method
Acacia nilotica	4912	4900
Dalbergia sisoo	5000	5000
Acacia modesta	5509	5500
Tamarix aphylla	4823	4835
E. camaldulensis	4900	4900

Table 9. Comparison of heat values of different wood species with Eucalyptus camaldulensis.

Wood sample	Calorific value (K. cal/g)		Reported	Percentage difference (%)
	Calculated			
	Empirical method	Calorimetric method		
Acacia nilotics	4912	4900	4900	Nil
Dilbergia Sisoo	5000	5000	5000	Nil
Acacia modesta	5509	5500	5500	Nil
Tamarix Aphylla	4823	4835	4835	Nil
Euc. Camaldulensis	4900	4900	4900	Nil

CONCLUSION AND RECOMMENDATIONS

This study examined the agro-forestry and energy potential of eucalyptus plantation on problematic soils. This study found that Eucalyptus, Farash, Kikar and Shisham were the dominating species cultivated by the farmers. Majority of farmers (72.5%) had cultivation of trees on boundary. Farmers had average number of 13.34 trees in an acre whereas average 126.97 trees on total farm area. Rice was the major crop cultivated by 55% of farmers due to soil salinity and water logging problems. Rice helped farmers to earn rupees 45000-rupees 60000 per acre. In addition, Agro-forestry was significantly contributing economically to the farmers as they were getting rupees 40000- rupees 50000 per Anum from the trees along with major crops i.e. rice, Moong, wheat and Corn. As for as energy potential was concerned, highest calorific value of Eucalyptus camaldulensis is reported as 4900 in normal soil. Whereas, this study shows that calorific value of eucalyptus camaldulensis in saline soil is also 4909 and as in water logged soil is 4750 K. cal/g which is approximately close to the normal soil. These findings confirmed that saline and water-logged soils have strong potential for energy plantations. Treated saline soils and treated water-logged soils are appropriate for eucalyptus cultivation. Therefore, saline and water-logged soils should be utilized for Eucalyptus planting as excellent results in saline and water-logged soils were witnessed with treatment. It is recommended that saline soils and water-logged soils should be preferred for eucalyptus camaldulensis plantation especially in afforestation programs like Ten Billion Tree Tsunami Project (TBTTP), Sustainable Land Management Project (SLMP) and Sustainable Forest Management project (SFM) etc.

REFERENCES

Bennett, S. J., E. G. Barrett-Lennard and T. D. Colmer. 2009. Salinity and waterlogging as constraints to saltland pasture production: A review. Agriculture, Ecosystems & Environment, 129: 349-60.

Cavalett, O., S. Norem Slettmo and F. Cherubini. 2018. Energy and Environmental Aspects of Using Eucalyptus from Brazil for Energy and Transportation Services in Europe. Sustainability, 10: 4068.

Cullen, P. 2003. Salinity. In Ecology – An Australian Perspective (eds P.M. Attiwill & B.A. Wilson), pp. 474–488. Oxford University Press, Melbourne, Australia. Place Published.

Doughty, R. W. 2000. The Eucalypts. A Natural and Commercial History of the Gum Tree Johns Hopkins University Press, Baltimore, MD, USA. Place Published.

Feikema, P. M., J. D. Morris and L. D. Connell. 2010. The water balance and water sources of a Eucalyptus plantation over shallow saline groundwater. Plant and Soil, 332: 429-49.

Hardiyanti, A. Umar, Makkarennu, S. Millang and B. Putranto. 2021. Contribution of agroforestry on farmers' income in Mapilli Polewali Subdistrict, West Sulawesi Province. IOP Conference Series: Earth and Environmental Science, 886: 012027.

Kassie, G. W. 2017. Agroforestry and farm income diversification: synergy or trade-off? The case of Ethiopia. Environmental Systems Research, 6.

Kawarasaki, S. H., H. Hamano, S.-i. Aikawa, H. Utsugi, M. Saito, H. Tanouchi, T. Kojima and K. Yamada. 2010. Growth of Trees Planted for Rehabilitation of a Saline Area of the Wheatbelt in Western Australia. Japan Agricultural Research Quarterly: JARQ, 44: 37-43.

Kidanu, S., T. Mamo and L. Stroosnijder. 2005. Biomass production of Eucalyptus boundary plantations and their effect on crop productivity on Ethiopian highland Vertisols. Agroforestry Systems, 63: 281-90.

Peck, A. J. and T. Hatton. 2003. Salinity and the discharge of salts from catchments in Australia. Journal of Hydrology, 272: 191-202.

World Bank. 2006. Carbon finance at the World Bank. http://carbon-finance.org/ accessed Dec. 20, 2007. Place Published.

Zada, M., S. Zada, M. Ali, Y. Zhang, A. Begum, H. Han, A. Ariza-Montes and L. Araya-Castillo. 2022. Contribution of Small-Scale Agroforestry to Local Economic Development and Livelihood Resilience: Evidence from Khyber Pakhtunkhwa Province (KPK), Pakistan. Land, 11: 71.