

Conversion of land utilization, Chickpea to Eucalyptus on marginal lands for the betterment of countryside

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Article Info

Keywords:

Agri-silviculture, Marginal lands, Land use potential, Benefit cost ratio, Internal rate of return.

Date:

Received: 22 March 2023

Accepted: 17 August 2023

Published: 30 December 2023

Volume: 02 (01), 2023

Abstract

Sustainable food production under climate change and reduced water resources is a real challenge, especially when considering the marginal lands of dryland systems. Marginal land is defined as land with little or no agricultural or industrial value, almost no profit potential, usually poor soil, located on the edge of desert or other desolate areas. Agri-silviculture systems have received more and more attention because of their multi-functional role and as a sustainable development model in rural areas. In certain areas of Pakistan, especially, in Punjab province, the farmer community rapidly plants *Eucalyptus camaldulensis* instead of chickpea and compact plantations on marginal land due to better land use patterns. This change in cropping scheme and introduction of exotic species can change the scenario of the farmer community in a short duration. The study was designed to determine the effect of land use changes in favor of farmer community benefits through *E. camaldulensis*. The result shows that the potential of marginal lands can be increased easily by changing the land use pattern. Earning from *E. camaldulensis* is much more than chickpea crop per year reducing the initial cost. In the future, this change in land use patterns on marginal lands will prove an economic jump in the countryside improving the lifestyle of rural people, as well as soil physio-chemical properties.

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1. Introduction

Land use is a general term used to demonstrate activities that are done on a piece of land. Land use conversion is one of the most important drivers of global ecosystem service changes, affecting human well-being and threatening the survival of other species (Foley *et al.*, 2005; Metzger *et al.*, 2006; Nelson *et al.*, 2006). In many regions of the world, spatial planning is the main policy tool that affects the distribution of land uses within a jurisdiction (Willis and Keller, 2007). Despite the increasing literature, the use of the concept of ecosystem services to support the actual decision-making process is still limited. There is a need to integrate ecosystem services from the conceptual framework and theoretical practice. This is credible and can be replicated, scalable and sustainable in possible future (Daily and Matson, 2008). In these exercises, different assumptions are made about the potential driving forces and the magnitude of land use changes to construct future visions. Polasky *et al.*, (2011) constructed different land use scenarios by changing the speed of urban, agricultural and forestry expansion. Pakistan is the sixth most populous country in the world and 4th in Asia, having an estimated population of 208.57 million in 2019- 2020 with a 2.1% growth rate. Pakistan moved from the 13th largest country in 1950 to the 6th largest country in 2016 and under current circumstances, it is expected that Pakistan can attain a fifth position in 2050. Pakistan is an underdeveloped country, more than 80 percent people of the country have land owners of four acres so their per capita income is very low. The rapid population growth has resulted in greater demand for timber, food, infrastructure and other basic needs. According to the report, nearly 39% of Pakistanis live in multidimensional poverty. The huge influence of trees on the stability and development of a country like Pakistan is undeniable (Sheikh, 1993). Trees are one of the most precious resources, which can bring some tangible and intangible benefits and greatly help improve the environment. These measures include absorbing pollutants, reducing traffic noise, windbreaks and shelterbelts, and reducing radiation and solar heat obtained through shading and evapotranspiration (Hiemstra *et al.*, 2008; Forest Research, 2010). Appropriate agroforestry practices can play an important role in alleviating poverty and increasing the income of farmers' communities through various intangible services (Afzal, 2016).

The surveyed areas of Pakistan for the continuous production of ordinary and special crops, as well as the potential for forestry or pasture development. Category IV includes those with severe restrictions on poor or marginal agricultural land (SSP, 2016). Marginal afforestation not only provides economic returns for farmers, but also makes great contributions to environmental services such as reducing soil erosion, stabilizing dunes, regulating microclimate, and sequestering carbon (Nunes *et al.*, 2011; Sauer *et al.*, 2012; Djanibekov *et al.*, 2013). Many previous studies have analyzed the beneficial effects of marginal farmland afforestation on socio-economic improvement and soil fertility increase (Djanibekov *et al.*, 2013; Janibekov and Kamgina, 2014; Nawaz *et al.*, 2013). Noorpur Thal range is located in District Khushab. It has extreme seasonal temperature changes, it is very cold in winter and very hot in any other desert in summer. Noorpur Thal is facing major problems of water shortage and wind erosion on marginal agricultural land irrigated by rainwater. Farmers in this area are rapidly adopting eucalyptus-based agroforestry systems on their rain-fed marginal farmland (Qureshi *et al.*, 2010). In the past, farmers used to plant chickpeas (grams), but the recently introduced agroforestry technology has encouraged farmers to switch from monoculture of chickpeas to pure stands (compact planting) of exotic eucalyptus (sufaida) because of expectations profits are better. Land use changes from rain-fed agriculture for growing chickpeas to eucalyptus-based compound forestry may affect ecosystem services.

E. camaldulensis is one of the most popular planting options on sandy and problematic land. Plantations on marginal lands also provide a variety of wood and non-wood forest products such as pulp, fuel wood, and wood (Mahmood *et al.*, 2001; Deka Press, 2016). Because of the ability of eucalyptus to compact sand, for land reclamation, eucalyptus is often planted on marginal land (Marcar and Benyon, 2003). However, in the Noorpur Thal Range area of the Khushab, the farm cultivation of *E. camaldulensis* is remarkable. Farmers in Noorpur Thal only grow chickpeas. The production of chickpeas is completely dependent on rainfall, and they earn nominal profits. In some villages, due to various internationally funded projects supervised by the Ministry of Forestry, a large number of *E. camaldulensis* plantations have been carried out. *Camaldulensis* is a kind of eucalyptus that grows quickly, is easy to sell, and is in high demand. It is very famous among farmers in the Noorpur Thal area (Qureshi *et al.*, 1993). So far, Pakistan has not researched the impact of eucalyptus-based land use systems on marginal land to provide usable information on its economic impact. We cannot only promote agricultural use but not agricultural trees. Here, we require the use of limited resources on marginal land for afforestation to maximize yield. Considering the impact of eucalyptus on farmers' income and land use changes is beneficial to eucalyptus. The purpose of this study is to estimate the profitability of marginal land by determining the net present value (NPW), benefit-cost ratio (BCR), internal rate of return (IRR), and production possibility curve of marginal land.

2. Materials and Methods

2.1 Study site

Noorpur Thal is a Tehsil in District Khushab, located at 31°98' north latitude and 71°91' east longitude. The climatic conditions are very harsh because the winter is very cold (the lowest daily temperature is below 0°C) and the summer is very hot (the highest daily temperature is 50°C), like any other pasture. The average annual rainfall is about 274 mm. The hottest month is June and the wettest month is July.

Table 1: Climatic conditions of the study area

Month	1	2	3	4	5	6	7	8	9	10	11	12
Precipitation (mm)	13.0	17.0	22.0	13.0	11.0	23.0	69.0	64.0	29.0	3.0	4.0	6.0

Max-Temp (°C)	20.1	22.6	27.7	34.1	39.4	42.0	38.5	37.2	36.9	34.1	28.0	22.3
Min-Temp (°C)	4.0	7.3	12.7	18.4	23.1	27.4	27.6	27.0	24.2	17.6	9.9	4.8
Avg-Temp (°C)	12.0	14.9	20.2	26.2	31.2	34.7	33.0	32.1	30.5	25.8	18.9	13.5

(Nawaz *et al.*, 2017)

2.2 Land use system

The main area of Noorpur Thal is composed of desert and marginal land. Marginal land refers to land whose production value is equal to the cost of planting. They are located on the edge of a desert or other isolated areas. Due to drought, the local people mainly grow grams. They sow the seed of chickpea before the rainy season. If there is sufficient rainfall in time, lush green bean crops can be obtained, about 370-500 kg/ha. Now, the people are turning the land use to *E. camaldulensis*. About 1793 trees are planted per hectare with a row-to-row spacing of 6 feet and a plant-to-plant spacing of 10 feet. In the first year, they irrigated eucalyptus seedlings with groundwater. After that, trees obtain water from the soil and also rely on rainfall. After 3-5 years, eucalyptus plantations are sold in the local market. The second planting was developed through shrubs. Therefore, in eucalyptus plantations, there are only 5 age groups between 1 and 5 years old to choose from.

2.3 Net present worth (NPW)

It is the difference between the present value of discounted proceeds and the present value of discounted costs. This is the most direct method of discounting cash flow. The official standard for measuring the present value of a project is to accept projects with a positive net present value. Hence,

$$NPW = PWB - PWC \text{ Where, } NPW = \text{Net Present Worth, } PWB = \text{Present Worth of Benefit stream}$$

$$PWC = \text{Present Worth of Cost stream the discount factor } 1/(1+i)^n \text{ determines the size of NPW.}$$

$$\text{Where, } i = \text{Discount rate, } n = \text{Number of years}$$

2.4 Benefit cost ratio (BCR)

It is the benefit and cost discount ratio. The benefit cost ratio is used almost exclusively as a measure of social benefit at the prevalent opportunity cost of capital in the country. It is used to evaluate projects and the formal decision criterion is to accept a project if the B/C ratio is one or more, when discounted at the opportunity cost of capital. Hence,

$$BCR = PWB / PWC \text{ Where, } BCR = \text{Benefit Cost Ratio, } PWB = \text{Present worth of Benefit stream, } PWC = \text{Present worth of Cost stream}$$

2.5 Internal rate of return (IRR)

It determines the average profitability of the project. It is the standard used by the World Bank for economic and financial analysis of all projects, as are most other international financial institutions. Hence,

$$IRR = LDR + \text{Diff. between two discount rates (NPW at LDR) Absolute difference between NPW of two discount rates.}$$

$$\text{Where, } IRR = \text{Internal Rate of Return } LDR = \text{Lower Discount Rate}$$

3. Results

3.1 Cost and benefit analysis of Eucalyptus and Gram

The results showed that the cost of a gram is equal every year because inputs used in each season are same and trend line shows that it will remain same in coming years if the input prices will not change. The income generated each year is also the same. The trend line shows the constant trend in the next years if the prices of output remain constant. These trends can be depicted as given in Fig. 1. Strictly diminishing cost trend is observed for eucalyptus because as it grows ploughing, labor, pesticides and other costs keep decreasing. Trend equation $Y = -5844.4x + 24560$ suggests that every year cost keep decreasing. But the income trend line for eucalyptus shows increase in gains every year @ 65000 rupees on an average. Cost is consecutively decreasing and income is increasing which is also going on in coming years. These behaviors of cost and income for eucalyptus are shown in Fig. 2. The cost of gram is constant throughout five years of crop production because there is almost no change in the prices of inputs (labor) and outputs. However, the cost of eucalyptus is strictly declining due to less role of working labor as a eucalyptus tree gets older and older. This declining cost results increases in returns for upcoming years because cost to benefit ratio keep increasing due to decreasing cost of labor and increasing benefits from the sale of leaves. This is best depicted in Fig. 3. Profit from eucalyptus production is increasing slightly for the first four years from the sale of leaves but in the fifth year, it goes up because it is its payback period and the farmer gets income from the sale of wood. But for gram production, the profit is constant every year because there is no considerable change in prices and productivity. These behaviors are adequately shown in Fig. 4.

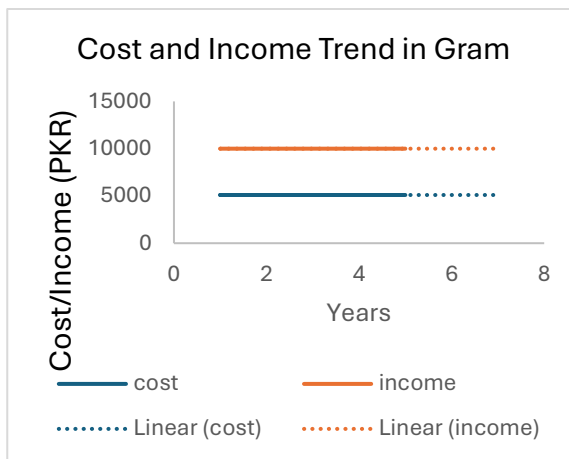


Fig. 1 Cost and income trend in Gram

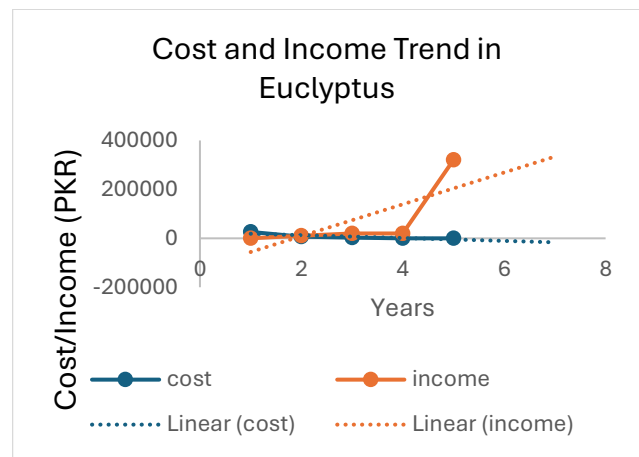


Fig. 2 Cost and Income Trend in Eucalyptus

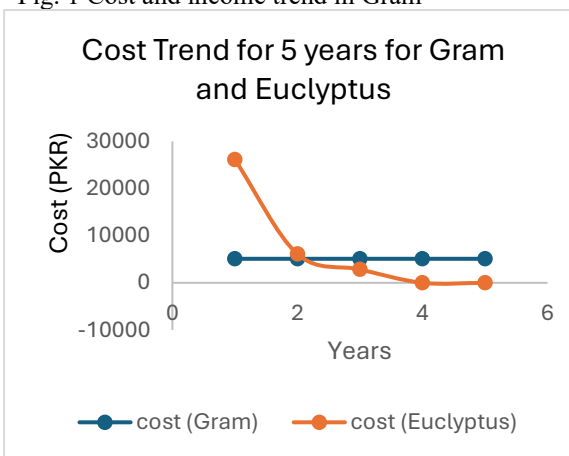


Fig. 3 Cost Trend for 5 years for Gram and Eucalyptus

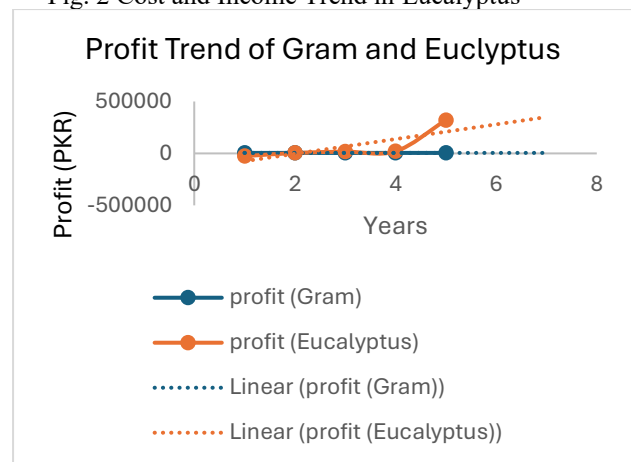


Fig. 4 Profit Trend of Gram and Eucalyptus

3.2 Production Possibility Frontier (PPF)

The production possibility frontier is a graph portraying all possible output combinations of two goods with a given set of inputs. A PPF is drawn for a farmer having fixed land area of 10 acres where he was growing gram from several years but he was told that growing eucalyptus is more profitable. He started the allocation of land and labor towards eucalyptus production. If the farmer allocates 10 acres to gram, he gets 10 thousand kilograms of gram and if he allocates this whole land for eucalyptus he gets 500 m³ of wood. When he saw profit in eucalyptus he changed his allocation from gram to eucalyptus which is depicted in Fig 5. In this case, the opportunity cost is constant everywhere, so linear PPF is produced. It is a situation, where resources are not specialized and can be substituted for each other. Products requiring similar resources will have constant opportunity costs.

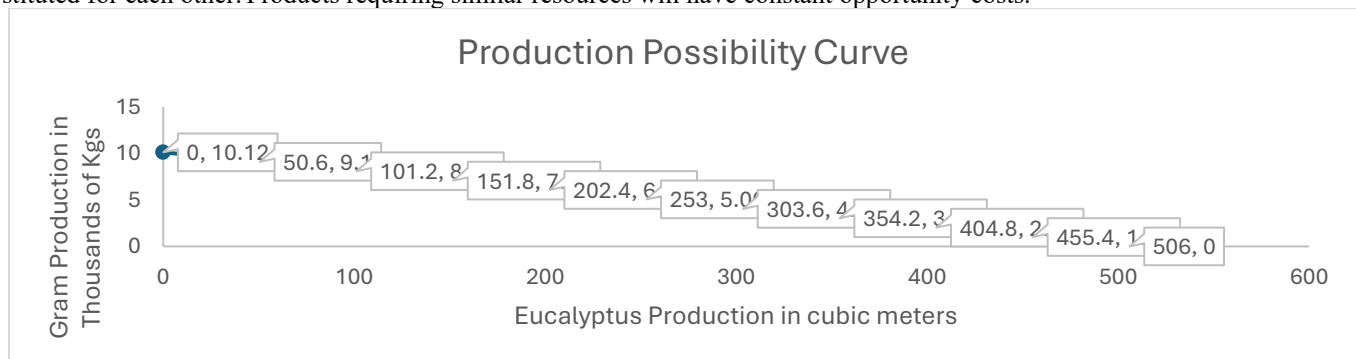


Fig. 5 Production possibility curve in Gram and Eucalyptus

3.3 Conversion of land use pattern grams to eucalyptus tree crop on marginal lands.

Table 1.1: Land use change pattern

Gram			Eucalyptus		
Area (Acre)	Production (kg)	Five-year production (kg)	Area (Acre)	Biomass Production (m ³)	Five-year biomass production (m ³)
10	2024.2	10121	0	0	0
9	1821.78	9108.9	1	10.12	50.60
8	1619.36	8096.8	2	20.24	101.2
7	1416.95	7084.7	3	30.36	151.8
6	1214.52	6072.6	4	40.48	202.4
5	1012.1	5060.5	5	50.60	253
4	809.68	4048.4	6	60.72	303.6
3	607.26	3036.3	7	70.84	354.2
2	404.84	2024.2	8	80.96	404.8
1	202.42	1012.1	9	91.08	455.4
0	0	0	10	101.2	506

BMP = $n \times p$ (n=number of acre), (p=production per acre)

3.4 Benefit-Cost Ratio (BCR)

A benefit-cost ratio is used in cost-benefit analysis which summarizes the general value of money for a particular project. A BCR is defined as the ratio of the benefits (of a project or proposal), in the form of money, with relation to costs, stated in monetary terms. For eucalyptus $BCR = 370000/35132 = 8.66$,

For Gram $BCR = 50000/25500 = 1.96$

BCR suggests that growing eucalyptus is much more beneficial than gram.

3.5 Net Present Value

Net Present Value (NPV) is the calculation used to find today's value of a future stream of payments. NPW for gram = 20696.85, NPW for eucalyptus = 249351.12

The NPV of both projects is positive, which means both are profitable. But NPV is a really big number in the case of eucalyptus. It means growing eucalyptus is more profitable than gram.

3.6 Internal rate of return

The internal rate of return is a method of calculating the rate of return. The term internal refers to the fact that the internal rate excludes external factors, such as inflation, the cost of capital, or various financial risks. "Internal rate of return is the rate of return at which NPV becomes zero". This is so high rate of return from other opportunities that makes our current project useless.

IRR (gram) = 28%, IRR (eucalyptus) = 67%

IRR also suggests that the production of eucalyptus is much more profitable than a gram.

4. Discussion

Sustainable agricultural practices are vital for rural development, particularly in regions with marginal lands, where environmental and economic constraints are pronounced. This discussion focuses on the cost and benefit analysis of cultivating *Eucalyptus camaldulensis* compared to gram (chickpea) on marginal lands in Punjab, Pakistan. By examining cost trends, income patterns, production possibilities, and financial metrics such as Benefit-Cost Ratio (BCR), Net Present Value (NPV), and Internal Rate of Return (IRR), this analysis highlights the sustainability and profitability of these agricultural choices. The cost of gram production remains constant over the years due to the stable prices of inputs like labor, seeds, and fertilizers. Consequently, the income generated from gram production also remains steady, provided market prices for gram do not fluctuate significantly (Bhatti and Sarwar, 2021). As shown in Fig. 1, both cost and income trend lines for gram are horizontal, indicating no expected changes shortly. This predictability offers security but limits opportunities for significant financial growth.

Conversely, the cost of cultivating *Eucalyptus camaldulensis* declines over time. As the trees mature, the need for intensive labor and inputs such as pesticides decreases, leading to lower annual costs (Khan and Ali, 2019). The trend equation

$Y = -5844.4x + 24560$ illustrates this downward trajectory. Simultaneously, income from eucalyptus shows a consistent increase, averaging around 65,000 rupees annually (Ahmed and Hussain, 2020). This rise is due to the growing value of wood and by-products like leaves, which can be sold for additional revenue. The combination of decreasing costs and increasing income makes eucalyptus cultivation highly attractive for farmers (FAO, 2018). The profit trends for gram and eucalyptus further highlight the advantages of the latter. While profits from gram remain static due to constant costs and revenues, eucalyptus profits increase significantly after the initial years (Zafar and Saeed, 2022). Fig. 4 shows that profit from eucalyptus rises markedly in the fifth year, coinciding with the maturity of the trees and the sale of wood, representing a substantial income boost. This payback period underscores the long-term financial benefits of switching to eucalyptus cultivation.

The Production Possibility Frontier (PPF) visualizes the trade-offs between growing gram and eucalyptus on a fixed land area of 10 acres. Initially, a farmer growing only a gram would produce 10,000 kilograms annually. However, reallocating land to eucalyptus production changes this dynamic significantly (Bhatti and Sarwar, 2021). As depicted in Fig. 5, a linear PPF indicates constant opportunity costs, meaning resources can be efficiently shifted from gram to eucalyptus without significant productivity loss. This flexibility allows farmers to optimize their land use for higher profitability. The BCR is a crucial indicator of the financial viability of a project. For eucalyptus, the BCR is 8.66, calculated as the ratio of benefits (370,000 rupees) to costs (35,132 rupees). In comparison, the BCR for a gram is 1.96, based on benefits of 50,000 rupees and costs of 25,500 rupees (Bhatti & Sarwar, 2021). These figures demonstrate that eucalyptus cultivation offers a significantly higher return on investment than gram. The NPV calculation, which assesses the present value of future cash flows, also favors eucalyptus. The NPV for eucalyptus is 249,351.12 rupees, compared to 20,696.85 rupees for gram. Both projects have positive NPVs, indicating profitability, but the substantially higher NPV for eucalyptus confirms its superior financial prospects (Khan and Ali, 2019). The IRR measures the rate of return at which the NPV of a project becomes zero. For gram, the IRR is 28%, while for eucalyptus, it is 67% (Ahmed and Hussain, 2020). This significant difference underscores the higher profitability and attractiveness of eucalyptus as an investment option, providing returns far exceeding those from gram cultivation. The shift from gram to eucalyptus cultivation on marginal lands offers substantial economic benefits. Increased profitability from eucalyptus can enhance the livelihoods of rural farmers, providing them with higher and more stable incomes. This, in turn, can stimulate local economies, leading to improved infrastructure and services in rural areas (Zafar and Saeed, 2022). Eucalyptus trees, with their deep root systems, can improve soil structure and water retention, benefiting the overall health of the land. However, it is crucial to manage these plantations carefully to avoid potential negative impacts such as soil nutrient depletion and allelopathic effects, which can inhibit the growth of other plants (FAO, 2018). Sustainable management practices, including mixed cropping and periodic soil amendments, can mitigate these risks. The adoption of eucalyptus cultivation can also lead to significant social changes. Increased income and employment opportunities can reduce rural-urban migration, allowing communities to thrive locally. Furthermore, enhanced economic stability can lead to better access to education and healthcare, improving the overall quality of life in rural areas (Khan and Ali, 2019).

Conclusion

The analysis indicates that transitioning from gram to eucalyptus cultivation on marginal lands in Punjab is highly beneficial from both economic and environmental perspectives. The declining costs and increasing incomes associated with eucalyptus, along with favorable financial metrics such as higher BCR, NPV, and IRR, make it a more attractive option for farmers. While both crops are profitable, the superior returns from eucalyptus offer a promising pathway for sustainable rural development, enhancing the livelihoods of farmers and contributing to the overall socio-economic transformation of rural communities.

Acknowledgment

The authors are grateful to the Department of Forestry and Range Management, University of Agriculture Faisalabad for technical support.

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