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Agroforestry Systems in North-Western Himalayas, India: An Overview

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Abstract

The Agroforestry systems practiced traditionally in Himalayan region are witnessed by the trees retained by farmers on their farmland. This traditional sustainable land use may be driven by topographical features, socio-economic conditions, cultural and aesthetic values in the region. For the development of any location-specific agroforestry technology, understanding the basis as well as goals towards which it is to be directed plays an important role. With the time human population has increased, rapid urbanization and industrialization increasing demand an alternate land use system tending to cope with the developmental activities in a sustainable manner. Agroforestry technology acts as a cushion against the ecological hazards associated with the developmental activities. The present article is an overview of the various agroforestry practices prevalent and their structural composition in different agro-ecological zones, along with their potential bio-economic productivity, in Himachal Pradesh of North-Western Himalayan region. Agri-silviculture, agri-horticulture, agri-silvi-horticulture, agri-horti-silviculture, horti-silviculture, silvi-pasture, pastoral-silviculture, agri-silvi-pasture, pastoral-silvi-horticulture, etc. are among different agroforestry systems in the region with structural composition varying as per needs and preferences of the farmers and suiting ecological conditions. The production potential in terms of biological productivity ranged between 5.13 ton ha⁻¹ and 198.20 ton ha⁻¹. Economically, the benefit and cost ratio of the systems varied from 1.23 to 5.77 depending on the nature of the components associated, expenses incurred, and the returns obtained from the systems. Further, being economically viable the important advantage associated with the agroforestry is the carbon storage potential helping in mitigation and adaptation to the changing climatic conditions. The carbon stock potential among different agroforestry systems varied from 29.72 ton ha⁻¹ to 109.93 ton ha⁻¹.

Keywords
Carbon; Himalayas; Land use; Productivity; Sustainability

1. Introduction

The Western Himalayas are more or less agroecosystems with 90 per cent of the inhabitants living in villages where agriculture, horticulture and animal husbandry are the primary sources of income (Atul, Punam and Kholsa, 1994). On the bunds of agriculture fields, various fodder, fruit, fuelwood and timber trees
are intentionally kept, and species composition varies according to land holdings and necessities of farmers (Toky, Kumar and Khosla, 1989). Planting trees on farms helps farmers satisfy their timber needs, and planting leads to an increase in tree cover and thereby reducing the burden on existing natural forests. This deliberate integration as well as retention of the trees in the farmland gives rise to a more or less sustainable land use system known as ‘Agroforestry’. Agroforestry systems can meet the needs of farmers under almost any set of environmental conditions. Farmers' investments are far less risky because they diversify their crop range and source of income, which reduces economic and social risks (Lefroy, 2009). In India, agroforestry is traditionally practiced in a variety of ways (Sharma, 1996; Solanki, 1998) and are based on the population's socio-economic, cultural, demographic factors, as well as farmers' experiences and other related factors. It has promoted an alternative land-use system to address various issues related to land use sustainability and environmental improvement, though scientific evidence is needed to determine its true potential. Agroforestry systems in India have diverse variations in their components both structurally and functionally, depending upon the temperature, elevation, soil structure and rainfall pattern (Combe, 1982; Nair and Dagar, 1991). Different agroforestry systems have been developed in various agro-climatic regions of the country, all of which have proven to be highly productive and environment-friendly. As they can include any of the crops, animals and tree species used in agriculture and forestry, agroforestry systems can take almost unlimited number of different forms. In order to support such efforts on a scientific basis, several activities have been undertaken in India, and, thus, India has become one of the leaders in agroforestry research (ISFR, 2013). The area under agroforestry is expected to increase from 25.32 million ha to 53 million ha in the next forty years; therefore, agroforestry will be contributing substantially to meet the requirements of the society through increased production and providing environmental benefits (Dhyani, Handa and Uma, 2013). In Himachal Pradesh and other Himalayan states, agroforestry has been practiced historically from time immemorial and it plays an important role in attaining sustainability in the hill farming systems. The diversity of agroforestry systems, their floristics, biomass production, carbon sequestration potential, soil amelioration, etc. in Himachal Pradesh have been described by Toky, Kumar and Khosla (1989) and Thakur, Gupta and Gupta (2004). Hill farming systems are dominated by small-scale, subsistence or near-subsistence agricultural groups. In comparison to larger and more financially oriented farms, these farmers have distinct land management goals and limits. Minimizing risk in food production, a lack of cash for farm inputs and necessities such as small timber and fuelwood, a lack of labour for intensive farming, and the gradual loss of community rights and resources are some of the constraints faced by typical small and intermediate land users in Himachal Pradesh hill farming systems.

With rapid urbanization and economic growth taking place in the country, there are several unprecedented opportunities for farming communities to supply farming products beyond subsistence level (ICAR, 2020). In Himachal Pradesh also, there is paradigm shift in hill farming systems shifting towards high value cash crops. For making such shifts, proper planning of the farming system beneficial to the stakeholders is necessary based on physical and environmental conditions for which the state of Himachal Pradesh is categorized into four agro-ecological zones as shown table 1. Agroforestry provides end-to-end link between
sustainability and profitability along with greater opportunities for the sustained productivity. The adoption of agroforestry technologies depends on the edaphic-climatic, socioeconomic status, and needs of the farmers, and the management is influenced by physical, demographic and institutional factors (Bayard, Jolly and Shannon, 2007). However, in recent years, changes in the climatic conditions, increase in human population and decrease in the size of agricultural landholdings have generated interest among farmers to adopt agroforestry systems. Climate change poses a great threat to agriculture and food security. The increasing land-use conflicts call for the development of land use systems that reconcile agricultural production with the provisioning of multiple ecosystem services, including climate change mitigation. To overcome the uncertainty of the monsoon and frequent natural calamities and to maintain food security, the farmers adopt a sustainable land-use system having diversified outputs, sustained agriculture productivity and diverse incomes. Agroforestry has been suggested as a global solution to increase land-use efficiency while reducing environmental impacts and economic risks for farmers (Paul, Weber and Knoke, 2017). Usually, lack of scientific knowledge, institutional approach and negative attributes of tree component (viz. long rotation, shade effect, allelopathy and large canopy) compel farmers to avoid adopting tree components in their fields. Agroforestry practices are more substantial, efficient and feasible for small and marginal farmers in Himachal Pradesh. The possibility of adopting agroforestry practices in Himachal Pradesh is very high as the farmers of Himachal Pradesh are now well educated and equipped with modern technology.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Zone</th>
<th>Elevation range (m)</th>
<th>Area (km²)</th>
<th>Per cent</th>
<th>Districts within zone</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Sub-Montane &amp; Low hills sub-tropical zone (Zone-I)</td>
<td>240-1,000</td>
<td>10,260</td>
<td>18.44</td>
<td>Kangra, Una, Hamirpur, Bilaspur, Solan, Chamba, Mandi, Sirmaur</td>
</tr>
<tr>
<td>2.</td>
<td>Mid-hills sub-humid zone (Zone-II)</td>
<td>1,000-1,500</td>
<td>4,664</td>
<td>8.38</td>
<td>Chamba, Kangra, Mandi, Shimla, Solan, Sirmaur, Kullu, Kinnaur, Hamirpur, Bilaspur</td>
</tr>
<tr>
<td>3.</td>
<td>High hills wet temperate zone (Zone-III)</td>
<td>1,500-2,500</td>
<td>9,217</td>
<td>16.56</td>
<td>Shimla, Mandi, Chamba, Kangra, Kullu, Solan, Sirmaur, Kinnaur, Lahaul &amp; Spiti</td>
</tr>
<tr>
<td>4.</td>
<td>High hills dry temperate zone (Zone-IV)</td>
<td>&gt;2,500</td>
<td>31,509</td>
<td>56.62</td>
<td>Kangra, Lahaul &amp; Spiti, Kinnaur, Chamba, Mandi, Sirmaur, Shimla</td>
</tr>
</tbody>
</table>

2. Prevalent Agroforestry Systems in Himachal Pradesh

Himachal Pradesh is characterized by the diverse agroecosystems as state varies in altitudinal ranges from 350 to 6,975 m above mean sea level that increases from West to East and from South to North (Gupta, Sarvade and Singh, 2017). With the altitudinal variation in the state, climatic conditions significantly vary affecting the farming practices. The farming practices, along with their composition, that are need based and comparatively more adaptive as well as productive in a particular region are commonly practiced by majority of the people. Various studies have been carried out in the Himachal Pradesh (Bammanahalli, 2016; Chisanga, Bhardwaj and Sharma, 2013; Goswami, Verma and Kaushal, 2014; Gupta, Sarvade and Singh, 2017; Jhanju, 2021; Kaler, Gupta and Negi, 2017; Kumar et al. 2018a, 2018b; Kumari, Sehgal and Kumar, 2008; Rajput, Bhardwaj and Pala, 2017; Salve and Bhardwaj, 2020; Thakur, 2020;
Tiwari, Pant and Singh, 2018; Toky, Kumar and Khosla, 1989) regarding the identification of the prevalent agroforestry practices in the state. Table 2 shows the various prevalent agroforestry systems present in the state and their composition of agricultural crops, forest trees, fruit trees and grasses at each agroecological zone. Mazumdar (1991) identified five farming systems at Nauni viz., agricultural system, horti-agriculture, horti-silvi-pastoral, grasslands and wastelands. Among the different systems, agri-horticulture system was the dominating system in the study area. Diagnostic survey of agroforestry systems in the sub-tropical and sub-humid regions of Himachal Pradesh by Kachru (1997) reported eight agroforestry system types viz., agri-silviculture, agri-horticulture, agri-silvi-horticulture, pastoral-silviculture, pastoral-horti-silviculture and pasture in the area. Sood (2006) identified traditional agroforestry practices in Mandi district of Himachal Pradesh and reported agri-silvicultural, agri-silvi-horticultural, silvi-pastoral, agri-horti-silvicultural, horti-agricultural and horti-silvicultural systems in the study area. In arid districts of Himachal Pradesh, Kumari, Sehgal and Kumar (2008) reported agri-horticulture (pea + potato + apple), agri-silviculture (pea + potato + kidney bean + Salix), agri-silvi-pastoral (pea + Salix + grasses), pastoral-silviculture (grasses + Salix) and pastoral-horticulture (grasses + apple) as the five major agroforestry systems in the Lahaul area. Agroforestry systems and their components were similar in Kinnaur district, except for lack of an agri-silvi-pastoral system which was found absent in Kinnaur. In this region, major tree species were willow, poplar and apple, first two being the source of fuel and fodder, whereas the third has now been introduced in the region as a horticulture cash crop. Goswami (2009) identified five agroforestry systems in the Kwaalkhad watershed in district Solan, namely agri-silvi-horticulture (maize, wheat, blackgram, Grewia, Ficus and pear), agri-horti-silviculture (wheat, kidney bean, tomato, pomegranate and Grewia), agri-silviculture (maize, barley, Ficus and Grewia), agri-horticulture (maize, Capsicum, tomato, plum and pear) and silvi-pasture (Pinus, Acacia and grasses). Singh (2014) reported agri-silviculture, silvi-pastoral, agri-horticulture, and agri-horti-silviculture systems in subtropical areas of district Sirmaur, Solan and Kangra of Himachal Pradesh. In Bilaspur and Hamirpur districts of Himachal Pradesh, Bammanahalli (2016) reported that the predominant systems in Bilaspur district were pastoral-silviculture (PS), agri-silvi-horticulture (ASH) and agri-silviculture (AS); whereas, in Hamirpur district, the predominant agroforestry systems were pastoral-silviculture (PS) followed by pastoral-silvi-horticulture (PSH) and agri-silviculture (AS). Kumar (2016) reported six different types of agroforestry systems viz. agri-silviculture, agri-silvi-pastoral, agri-silvi-horticulture, agri-horti-silviculture, horti-pastoral and silvi-pastoral in sub-tropical region of Solan district in Himachal Pradesh. Kumar et al. (2018b) identified the agroforestry systems in Kangadhat block of Solan district that included agri-silviculture, agri-silvi-pastoral, agri-silvi-horticulture, agri-horti-silviculture, horti-pastoral and silvi-pastoral systems. In Sirmaur district, Tiwari, Pant and Singh (2018) identified different land use systems viz., agri-silviculture, agri-horticulture, agri-silvi-horticulture, agri-silvi-pastoral, pastoral-silviculture, silvi-pastoral and pastoral-silvi-horticulture. In Shimla district, Singh (2019) reported that agri-silviculture, agri-horticulture, horti-agriculture, horti-pastoral, pastoral-horti-silviculture, pastoral-silviculture and silvi-pastoral were the major agroforestry systems. In altitudinal zone-I and Zone-II, the most predominant agroforestry system was agri-silviculture (AS), followed by agri-horticulture (AH) and silvi-pastoral (SP),
whereas, in altitudinal zones-III, IV and V, the most predominant agroforestry system was agri-horticulture (AH) followed by horti-agriculture (HA) and horti-pastoral (HP). In Chuhar valley of district Mandi, Thakur (2020) identified six types of agroforestry systems viz., agri-silviculture (AS), agri-horti-silviculture (AHS), agri-silvi-horticulture (ASH), horti-pastoral (HP), pastoral-silviculture (PS) and pastoral-silvi-horticulture (PSH). In the northern region, the most predominant agroforestry system was agri-horti-silviculture (AHS), followed by pastoral-silviculture (PS), whereas, in the southern region, the most predominant agroforestry system was pastoral-silviculture (PS) followed by agri-silviculture (AS). In Seraj valley of district Mandi, Jhanju (2021) identified seven different types of agroforestry systems where the horti-agriculture system was the predominant agroforestry system followed by agri-horticulture and agri-horti-silviculture. In the study area, pastoral-silviculture was the least used agroforestry system, which might be due to the lack of land for further diversification of existing land use systems, as pastoral-silviculture was not present in the marginal category of farmers. The prevalence of these systems in these districts may be attributed to local ecological conditions, to meet out the fodder demands of livestock, which are mainly reared to meet their daily needs.

3. Biological Productivity Potential of Agroforestry

Land is one of the fundamental resources required for agricultural and non-agricultural use with an irony that it is a fixed resource and can’t be expanded at will. To fulfil the ever-increasing needs of the people from the limited land resources available, it is important to increase the productivity of the available land resources by incorporating the plants having higher production potential per unit area. Plant productivity is a function of the net photosynthesis rate which is dependent on the gross photosynthesis and the respiration losses from the plant. However, the selection of tree species for agroforestry system is not only based on cultural, economic and environmental basis, but also on certain photosynthetic principles (Nair, 1993). It may be useful in selecting tree species for agroforestry that will increase the overall productivity in terms of biomass and economic returns from the system. The biomass production potential of the prevalent agroforestry systems in different agro-ecological zones present in the Himachal Pradesh has been worked out by several researchers (Bammanahalli, 2016; Gupta, Sarvade and Singh, 2017; Sharma et al., 2021; Kaler, Gupta and Negi, 2017; Singh, 2019; Toky, Kumar and Khosla, 1989; Goswami, Verma and Kaushal, 2014; Singh et al., 2015; Rajput, Bhardwaj and Pala, 2017; Chisanga et al., 2018; Singh et al., 2020; Thakur, 2020) as summarized in the table 3. Mazumdar (1991) carried out the research on biomass production pattern in traditional agroforestry systems in western Himalayas and reported that horti-silvi-pastoral system gave the highest standing biomass (355.5 quintal ha\(^{-1}\)) compared to horti-agricultural system (301.5 quintal ha\(^{-1}\)) and grassland (63.2 quintal ha\(^{-1}\)). Horticultural trees in horti-agricultural system produced the maximum biomass of 55.8 quintal ha\(^{-1}\) yr\(^{-1}\) at the highest rate of 18.5 per cent. Fruit trees also put the major portion of the annual biomass by 53.5 per cent to horti-silvi-pastoral system followed by fodder trees (26.0%) and timber/fuelwood trees (20.7%). In grassland system, timber/fuelwood species contributed the maximum share by 51.1 per cent to system productivity. Kumar (1996) conducted bio-economic appraisal of agroforestry systems in Himachal Pradesh and found that biomass productivity in
different agroforestry systems followed the order “agri-silviculture>agri-horti-silviculture>agri-horticulture>sole cropping”. As different system yielded 1.10, 1.23 and 1.31 times higher biomass in maize and lentil cropping pattern and 1.09, 1.22 and 1.29 times in the soybean and wheat cropping pattern than agri-horti-silviculture system, agri-horticulture system and sole cropping, respectively. Rajput (2010) reported the trend forest> silvi-pasture> agri-horticulture> horticulture for biological productivity of the different land use systems in Kullu district of Himachal Pradesh. Kumar (2016) conducted a study for the evaluation of existing agroforestry systems for biological productivity in the sub-tropical region of Solan district of Himachal Pradesh. The biological yield was found to be maximum (24.88 ton ha⁻¹ yr⁻¹) under silvi-pastoral among all the agroforestry systems attributed to preponderance of mature trees at the site, while minimum (12.16 ton ha⁻¹ yr⁻¹) was found under agri-horti-silviculture. Goswami et al. (2014) studied the biomass production potential of traditional agroforestry systems in Giri river watershed in Himachal Pradesh and found that, among all the systems, the agri-silvi-horticulture was having highest accumulated biomass averaging 222.63 quintal followed by agri-horti-silviculture (191.60 quintal), silvi-pasture (122.63 quintal), agri-horticulture (118.20 quintal) and agri-silviculture (108.56 quintal). Singh et al. (2019) conducted an experiment to identify variation in biomass production potential of eight land use systems viz. agriculture, horticulture, agri-silvicultural, silvi-pastoral agri-horticulture, agri-horti-silvicultural, forest and grassland at two altitudinal ranges (365-635 m amsl, 636-914 m amsl) of Himachal Pradesh. They found that the maximum value of aboveground biomass (184.75 ton ha⁻¹), belowground biomass (47.84 ton ha⁻¹) and total biomass (232.59 ton ha⁻¹) was in forest land use system with minimum aboveground biomass (2.43 ton ha⁻¹), below ground biomass (1.09 ton ha⁻¹) and total biomass (3.52 ton ha⁻¹) under pasture land use system. Among the agroforestry systems maximum aboveground (66.46 ton ha⁻¹), belowground (20.84 ton ha⁻¹) and total biomass (86.48 ton ha⁻¹) was accumulated in agri-horti-silviculture system with minimum aboveground biomass (34.49 ton ha⁻¹), belowground biomass (9.01 ton ha⁻¹) and total biomass (43.51 ton ha⁻¹) under silvi-pastoral system. The biomass production potential of different land use systems showed declining trend with increase in altitude. Sharma et al. (2021) assessed the biological productivity of the agroforestry system in the sub-tropical low hill zone of Himachal Pradesh and reported highest biological productivity in silvi-pastoral (31.02 ton ha⁻¹ yr⁻¹) system having higher mature tree density, while minimum (16.60 ton ha⁻¹ yr⁻¹) biological productivity was recorded for agri-horticulture system.

4. Economic Potential of Agroforestry in Himachal Pradesh

Besides various ecological benefits associated with agroforestry system, it has potential to meet the subsistence needs of the low-income households (Shukla, Pandey and Kumar, 2018). Integration of trees with agricultural crops ensures higher benefits depending upon the components associated in the system. Various studies highlight the economic potential of agroforestry in Himachal Pradesh ranging from Rs. 11,451 – Rs. 2,633,000 ha⁻¹ year⁻¹ yielding a benefit cost ratio 1.23- 5.77 (Table 4). However, the economic benefits of the system are mainly attributed to the components of prime importance integrated in the system. Besides the monetary benefits, agroforestry also has a great potential for
employment generation, thereby, ensuring and improving livelihood of the agriculture dependent communities. Agroforestry in the Indian Himalayan region has a potential of employment generation to a tune of 5.76 million mandays per year (Arunachalam et al., 2020). Agroforestry, thus, can be a suitable tool for the reduction of unemployment target of state government from 10.6% to 6% (GoHP, 2021). Further, growing of two or more components, simultaneously, on the same land unit minimizes the risk associated with the production from sole cropping. If one crop failure takes place, there is other component that can still produce and can help in the minimization of the losses from complete crop failure. Moreover, integrating livestock in agroforestry systems acts as a cushion and provides regular income to the households besides meeting out the nutritional demands. Sharma et al. (2008) evaluated the economics of a mandarin (kinnow) based agroforestry system in Himachal Pradesh with wheat and cauliflower - mustard. Average yields of wheat (18.68 quintal ha⁻¹) and cauliflower – mustard (10.34 quintal ha⁻¹) were reported beneath mandarin plants, which were lower than those of wheat (22.34 quintal ha⁻¹) and cauliflower – mustard (12.00 quintal ha⁻¹) grown in open fields. However, the overall return from the agri-horticulture system was higher than that of sole crops. Cauliflower – mustard cultivation with mandarin was shown to be more lucrative than wheat cultivation. The mandarin - cauliflower – mustard combination had the highest returns per hectare (Rs. 56,407.55). The bio-economic appraisal of different land use systems in temperate northwestern Himalayas was studied by Rajput (2010) in the Kullu district of Himachal Pradesh and revealed that the orchard + vegetable-vegetable land use system situated at 1,600-1,900 m amsl gave net profit of Rs. 1,023,430 ha⁻¹ yr⁻¹ in valley ecosystem, whereas, in the mountainous ecosystem, agri-horticulture land use system situated at 1,700-2,000 m amsl resulted in the net profit of Rs. 969,194 ha⁻¹ yr⁻¹. Total benefits (net profit + carbon credits) in the valley ecosystem were highest for orchard + vegetable-based cropping system at all the four altitudinal gradients. Similarly, in the mountainous ecosystem also, fruit based agri-horticulture system showed maximum total benefits at all the altitudinal gradients. Chisanga, Bhardwaj and Sharma (2013) assessed the bio-economics of several land-use systems in the dry temperate northwestern Himalayas and found that the agri-horticulture system produced the highest net profit (Rs. 1,310,000) followed by horticulture (Rs. 1,165,852); whereas, other land-use systems, such as agriculture, agri-horti-silviculture, silvi-pasture and barren land, had lower net returns than fruit-based land use systems. Thakur (2020) studied the economic productivity of different agroforestry system in northern and southern regions of Chuhar valley in Mandi District of HP and revealed that in northern region the economic productivity of agroforestry systems were in the order of Agri-horti-silviculture (Rs. 168,554 ha⁻¹ yr⁻¹) > Agri-silvi-horticulture (Rs.127,086 ha⁻¹ yr⁻¹) > Horti-pastoral (Rs. 104,779 ha⁻¹ yr⁻¹) > Pastoral-silvi-horticulture (Rs.15,873 ha⁻¹ yr⁻¹) > Pastoral-silviculture (Rs. 8,074 ha⁻¹ yr⁻¹), whereas, in southern region of the valley net returns followed the order Agri-silviculture (Rs.185,404 ha⁻¹ yr⁻¹) > Agri-horti-silviculture (Rs.176,660 ha⁻¹ yr⁻¹) > Agri-silvi-horticulture (Rs.165,117 ha⁻¹ yr⁻¹) > Horti-pastoral (Rs.132,836 ha⁻¹ yr⁻¹) > Pastoral-silvi-horticulture (Rs.13,113ha⁻¹ yr⁻¹) > Pastoral-silviculture (Rs.8,695 ha⁻¹ yr⁻¹). In Seraj valley of district Mandi, Jhanju (2021) found horti-agriculture system to be the most profitable with net returns of Rs. 206,830.44 ha⁻¹ yr⁻¹, while pastoral-silviculture with net returns of Rs. 15,634.63 ha⁻¹ yr⁻¹ was found to be less profitable in terms of net returns.
<table>
<thead>
<tr>
<th>Agro-climatic zones</th>
<th>Agroforestry systems</th>
<th>Major agricultural crops</th>
<th>Major forest trees</th>
<th>Major fruit trees</th>
<th>Major grasses</th>
<th>References</th>
</tr>
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<tbody>
<tr>
<td>Zone-II</td>
<td>Agrisilviculture, Agrisilvihorticulture, Agrihortisilviculture Agrisilvipastural, Agrihorticulture, Hortisilviculture, Silvipastural, Pastoralisilviculture</td>
<td>Maize, Blackgram, Tomato, Soybean, Colocasia, Kidney bean, Zinger, Capsicum, Wheat, Barley, Mustard, Gram, Pea, Cabbage, Cauliflower, Garlic, Onion, Turmeric</td>
<td>Grewia optiva, Celtis australis, Toona ciliata, Morus alba, Robinia, Bauhinia, Salix, Melia, Albizia, Acacia catechu, Pinus roxburghii, Quercus spp., Ficus spp., Bombax ceiba, Leucaena, Myrica esculenta</td>
<td>Peach Pear, Plum, Apricot, Apple, Walnut, Wild pomegranate</td>
<td>Dicnanthum annulatum, Themeda anathera, Chrysopogon montanus, Heteropogon contortus, Cymbopogon martini, Paspalum notatum</td>
<td>Goswami, Verma and Kaushal (2014); Gupta, Sarvade and Singh (2017); Kumar et al. (2018b); Rajput, Bhardwaj and Pala (2017); Singh (2014); Tiwari, Pant and Singh (2018); Toky, Kumar and Khusla (1989)</td>
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<td>Maize, Blackgram, Tomato, Soybean, Colocasia, Kidney bean, Capsicum, Amaranthus, Millets, Wheat, Barley, Mustard, Buckwheat, Gram, Pea, Cabbage, Cauliflower, Potato, Garlic, Zinger, Turmeric</td>
<td>Grewia optiva, Celtis australis, Toona ciliata, Morus alba, Robinia, Ulmus, Bauhinia variegata, Salix spp., Pinus wallitchiana, Quercus spp., Cedrus deodara, Fir spp., Spruce, Bombax ceiba, Rhododendron, Horse chestnut, Abies spp.</td>
<td>Apple, Peach, Pear, Plum, Apricot, Persimon, Wild pomegranate, Walnut, Almond, Pistachio nut</td>
<td>Cymbopogon martini, Themeda anathera, Cynodon dactylon, Apluda mutica, Andropogon nardus, Pennisetum clandestinum, Dactylis gloomerata</td>
<td>Chisanga, Bhardwaj and Sharma (2013); Goswami, Verma and Kaushal (2014); Gupta, Sarvade and Singh (2017); Jhanju (2021); Kumari, Sehgal and Kumar (2008); Kumar et al. (2018a); Rajput, Bhardwaj and Pala (2017); Salve and Bhardwaj</td>
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</table>
Table 3: Biomass production potential of most prevalent agroforestry systems in Himachal Pradesh, India

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<th>Agroforestry Systems</th>
<th>Biomass production</th>
<th>References</th>
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<td>Below ground biomass (ton ha$^{-1}$)</td>
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<td>12.66-53.29</td>
<td>4.15-13.47</td>
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<td>Agrihorticulture</td>
<td>10.69-60.58</td>
<td>3.53-13.51</td>
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<td>4.57-5.92</td>
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<td>16.93-70.91</td>
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<td>Silvipastoral</td>
<td>4.58-45.04</td>
<td>1.33-11.30</td>
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<td>Pastoralisilviculture</td>
<td>6.89-9.76</td>
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<td>17.60-18.02</td>
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<td>Below ground biomass (ton ha⁻¹)</td>
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<td>13.89 - 70.63</td>
<td>3.70 - 18.61</td>
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<td>Pastoral silviculture</td>
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<td>1.28 - 1.36</td>
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<td>Zone-III</td>
<td>Agrisilviculture</td>
<td>13.93 - 56.87</td>
<td>3.98 - 16.72</td>
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<td>9.58 - 52.12</td>
<td>3.25 - 15.29</td>
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<td>4.08 - 23.08</td>
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<td>17.66 - 77.63</td>
<td>6.87 - 21.17</td>
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<td>Pastoral silviculture</td>
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<td>Zone-IV</td>
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<td>24.58</td>
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<td>Agrihorticulture</td>
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<td>Silvipastoral</td>
<td>162.80 - 118.8</td>
<td>24.44 - 35.7</td>
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Table 4: Economic benefits of prevalent agroforestry systems in Himachal Pradesh

<table>
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<tr>
<th>Agro-climatic zones</th>
<th>Agroforestry System</th>
<th>Total Expenses (Rs. ha⁻¹ yr⁻¹)</th>
<th>Gross Returns (Rs. ha⁻¹ yr⁻¹)</th>
<th>Benefit Cost Ratio</th>
<th>References</th>
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<tbody>
<tr>
<td>Zone-I</td>
<td>Agrisilviculture</td>
<td>59,046 - 243,667</td>
<td>126,446 - 484,401</td>
<td>1.23 – 2.92</td>
<td>Bammanahalli (2016); Kaler, Gupta and Negi (2017); Sharma et al. (2021); Singh (2014); Singh (2019)</td>
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<td></td>
<td>Agrihorticulture</td>
<td>22,781 - 219,029</td>
<td>49,489 - 506,333</td>
<td>1.86 – 2.74</td>
<td>Bammanahalli (2016); Kaler, Gupta and Negi (2017); Sharma et al. (2021); Singh (2014); Singh (2019)</td>
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<td></td>
<td>Agrisilvihorticulture</td>
<td>63,461 - 234,494</td>
<td>120,071 - 462,631</td>
<td>1.86 - 2.00</td>
<td>Bammanahalli (2016); Kaler, Gupta and Negi (2017); Sharma et al. (2021)</td>
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<tr>
<td>Agro-climatic zones</td>
<td>Agroforestry System</td>
<td>Total Expenses (Rs. ha⁻¹ yr⁻¹)</td>
<td>Gross Returns (Rs. ha⁻¹ yr⁻¹)</td>
<td>Benefit Cost Ratio</td>
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<tr>
<td>Zone-I</td>
<td>Agrihortisilviculture</td>
<td>82,470 – 160,469</td>
<td>143,120 – 552,613</td>
<td>1.85 - 4.97</td>
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<td>Silvipastoral</td>
<td>8,349 – 14,540</td>
<td>14,342 – 52,156</td>
<td>1.78 - 5.77</td>
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<td>Agrisilviculture</td>
<td>29,141 – 180,802</td>
<td>64,632 – 380,814</td>
<td>2.05 - 2.24</td>
<td>Singh et al. (2015); Singh (2019)</td>
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<td>Agrihorticulture</td>
<td>28,882 – 171,935</td>
<td>65,166 – 293,563</td>
<td>1.52 - 2.33</td>
<td>Singh et al. (2015); Singh (2019)</td>
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<td>Silvipastoral</td>
<td>6,467 – 20,236</td>
<td>20,532 – 35,214</td>
<td>1.74-3.45</td>
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<td>Pastoralisilviculture</td>
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<td>33,940 – 447,100</td>
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<td>143,893-345,500</td>
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<td>Silvipastoral</td>
<td>6,467 – 97,200</td>
<td>21,908-647,000</td>
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<td>2.12 - 2.18</td>
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<td>Zone-III</td>
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<td>2.20 - 2.29</td>
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<td>Agro-climatic zones</td>
<td>Agroforestry System</td>
<td>Above ground carbon stock (ton ha(^{-1}))</td>
<td>Below ground carbon stock (ton ha(^{-1}))</td>
<td>Total vegetation carbon stock (ton ha(^{-1}))</td>
<td>Soil organic carbon stock (ton ha(^{-1}))</td>
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</table>

5. Carbon Stock Potential of Agroforestry

Agroforestry is a sustainable land use system that synergizes the climate change mitigation as well as adaptation strategies. Various advantages associated with agroforestry land use are food security, prevention of degradation of soil resources, increase along with stabilization of farm income through diversification, enhancement in employment opportunities, sequestration of carbon, etc. (Chavan et al., 2015; Sharma et al., 2020). The CO₂ concentration in Earth’s atmosphere is 413.20 + 0.2 ppm (WMO, 2021), which represents only a fraction of the CO₂ emitted as about 55% of it is removed by oceans and terrestrial vegetation. Forests being the lungs of the Earth have higher carbon sequestration potential than any other land use. Agroforestry has a high potential to sequester carbon from the atmosphere as compared to agricultural mono-cropping, thereby, helps in the mitigation and adaptation to climate change. The carbon storage potential of different agroforestry systems in Himachal Pradesh, as shown in table 5, depicts that agroforestry can store carbon ranging from 1.19- 71.61 ton ha⁻¹ in vegetation and 9.37- 56.70 ton ha⁻¹ as soil carbon with total carbon storage potential ranging from 29.72-109.93 ton ha⁻¹. Sequestering carbon through agroforestry land use also offers an additional economic opportunity through carbon trading in international market, thereby, mitigating climate change as well as meeting the societal needs through multiple products (Goswami, Verma and Kaushal, 2014). Further, it can be a way forward towards reduction of emissions by 10 per cent of 2012 emission levels upto 2022 as targeted by state government (GoHP, 2021).

6. Conclusion

From the above discussion, it can be concluded that, agroforestry being a sustainable land use system, certainly it is the need of the hour. Agroforestry technology at any area is ecologically driven for its structural arrangement as well as compositional difference. Through agroforestry farmers, especially in mountainous region facing multiple constraints can push productivity in desired direction guided by the need-based approach and can harness biological and economic benefits. Marginal and small farmers can reap higher economic benefits from small land units by adopting horticulture-based systems. Fodder tree-based farming systems can solve the dual objectives of fodder scarcity as well as uplifting livelihood status of farming families. Further, having higher carbon storage
potential agroforestry land use can be used as the productive as well as protective tool to mitigate and adapt to changing climatic scenarios.

7. References


Author’ Declarations and Essential Ethical Compliances

Authors’ Contributions (in accordance with ICMJE criteria for authorship)

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Environmental Effectiveness of Greening Measures under the Common Agricultural Policy of European Union

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Abstract
The objective of this study is to evaluate the effectiveness of greening measures in the European Union during the period of 2014-2020. Studies carried out in various EU Member States by the European Court of Auditors and other independent authors estimated changes in farming practices as a result of greening over the period of 2014-2020 to be between 2% and 5% of the EU’s agricultural area. The widest audit of greening performed by the European Court of Auditors in 2017 shows that the greening process induced changes of approximately 5% were divided as follows: 1.8% for crop diversification, 2.4% for ecological area and 1.5% for permanent grassland. Contrary to the low efficiency of greening, the payments made were on an average €80 per hectare, while the costs for its implementation are on an average €25-30 per hectare. Although the payments far exceed the costs incurred, little benefits were achieved on improved soil quality, biodiversity conservation and a reduction in Greenhouse Gases (GHG) by 2% only at EU level. Had the European Commission’s original and more ambitious proposal been adopted, GHG reductions would have reached 5% threshold level. Conclusively, greening is a complex measure having significantly low effectiveness in context of the degree of environmental protection offered by it.

Keywords
Common agricultural policy; Greening; Greenhouse gases; European Green Pact 2030

1. Introduction

Global warming has intensified over the last two centuries due to the increase in Greenhouse Gas (GHG) emissions, representing one of the greatest threats to mankind. Agriculture is a major contributor to GHG emissions, accounting for 10% - 11% of total emissions in the European Union (EU) Member States. Globally, this share is higher where the food and agriculture sectors contribute 30% of total GHG emissions (Wollson et al. 2021). The main emissions from this sector are nitrous oxide (N₂O), methane (CH₄) and carbon dioxide (CO₂). Europe is the main pillar involved in the fight against climate change and has adopted numerous strategies and policies to this effect in order to become a climate neutral continent by 2050. Of particular importance is the
Common Agricultural Policy\(^1\) (CAP) of EU. It is a set of systems and processes that contribute to sustainable development, food security and the fight against climate change. The Common Agricultural Policy was established through Treaty of Rome 1957\(^2\). Before the CAP, a Stresa Conference 1958\(^3\) was organized to establish the principles of single market in the EU, the principle of community preference and the principle of financial solidarity. The Common Agricultural Policy was the answer for the challenges that appeared after the Second World War, flagging the need for increasing the production of food and supporting the international competitiveness by granting subsidies on production, which turned the European Union into an agricultural hub.

The artisan of CAP was Sicco Mansholt\(^4\), who created a plan for a common market in Europe in 1950. This idea received more support since 1958 when he became the first Commissioner for Agriculture in the European Commission, and 4 years later, in 1962, the CAP came into force. This Policy produced the first impacts in 1964 through uniform prices. On the perseverance of Mansholt, in 1968, the European Commission forwarded the “Memorandum for the Reform of Common Agricultural Policy”, known as the ‘Mansholt Plan’. This plan set out the development of farms as an essential condition for modern agriculture. The quest of farmers for subsidies led to the appearance of the supra-production phenomenon and the increase in consumption of chemicals, thus amplifying the pressure on the environment. Therefore, since 1980 the rights of farmers to secured revenues were limited depending on the maximum level of production.

In the beginning, payments under this policy were linked to production; following Ray McSharry’s reform of 1992 under which compensatory payments were decoupled from production and were fixed on per hectare and per animal bases. Following the 1999 Agenda and reform of 2000, the CAP was split into Pillar I (market and direct producer support measures) and Pillar II (structural and rural development measures). Since 2003, new directions were set out through the document ‘Towards Sustainable Farming’. This document represents a mid-term review of the CAP by the European Commission (EC), whereby environmental care and rural development received increased attention. The major changes were made by the reform of Fischler in 2003, when the payments were decoupled from production. The payments were introduced basing the observance of environmental conditions, and an increased attention was paid to the sustainable rural development measures.

The latest reform of 2013 provided a fairer targets of subsidies and differentiated itself through a feature called ‘greening’, which is a component of Pillar I. Through greening, farmers are rewarded for applying the practices beneficial to the climate and the environment. Such measures include maintaining permanent grassland, diversifying crops and introducing ecological focus areas. In addition to greening, there are other mandatory environmental benefits in Pillar I, namely cross-compliance with the standards of good agricultural and environmental condition (GAEG) and statutory management requirements.

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3. https://www.cvce.eu/en/education/unit-content/-/unit/02bb76df-d066-4c08-a58a-d4686a3e68ff7928d22e-eb5f-4e34-8f08-2f8b3c129ca1/Resources
(SMR). Pillar II includes voluntary environmental measures apart from rural development measures.

2. Methodology

The basis of this research is the Report 21/2017 of the European Court of Auditors, a vast report drawn based on the working documents of the European Commission and its correspondence with the Member States, to which we can add the legislation in force and the many visits on the field made by the European Court of Auditors in the main general directorates of the European Commission and in five EU Member States (European Court of Auditors, 2017).

The intervention logic in terms of costs in relation to changes in farming practices and environmental benefits was analysed on the basis of a needs assessment, the European Commission’s initial proposal and the final version of the reform for the period of 2014-2020. The needs assessment was carried out by the EC through a very comprehensive study in 2011, looking at the best policy options in terms of their contribution to environmental protection for the period of 2014-2020 and is shown in figure 3.

The following methods were used to conduct this research: analysis, synthesis, logic, comparison and graph method.

Analysis

Analysis represents the main method used in this research. By this method, the authors mainly analysed the result indicators provided by the European Commission regarding the impact of greening on environment and of the budget of Common Agricultural Policy, but also the impact determined by the European Court of Auditors.

Synthesis

The role of synthesis in this study is the collection of information from the specialized literature regarding the greening effects on the environmental factors and their presentation under the form of a simple and focussed study from the point of view of information transmitted.

Logic

This method represents the essence of this study and targeted the determination of the intervention logic of greening by evaluating the ratio between the payments made as subsidies to the farmers, the benefits brought to the environment and the costs incurred for implementation of greening.

Comparison

Due to multiple studies analysed regarding the implementation of greening, some studies performed before and after implementation, this method consists of the basis of comparison of results from the specialized literature and the exact establishment of the impact resulted by its implementation. Also, by comparison, authors presented different forms of greening proposed and adopted, and the results obtained depend on the form adopted.

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5 https://www.eca.europa.eu/Lists/ECADocuments/SR17_21/SR_GREENING_RO.pdf
Graph method

The interconnection and interdependence of research methods presented in this research were supported by the graphical representation of results obtained. Graphically represented were the situation of agricultural areas in EU, the changes produced after the implementation of this agricultural policy, the various legislative proposals for implementation of greening and the stages in which greening has lost a part of its complexity and ambition.

3. Results and Discussion

Cost-benefit analysis following the implementation of greening measures

A key factor behind biodiversity erosion and ecosystem degradation is agricultural intensification. It contributes equally to the climate change (Díaz et al., 2019; Shukla et al., 2019). In this context, Pe’er et al. (2019) assessed that these measures are insufficient compared to the environmental impact of agriculture. As early as 2012, Westhoek et al. (2012) warned that crop diversification and grassland maintenance only apply to 2% of the EU agricultural area, insufficient to achieve notable climate and environmental results. Crop diversification is considered the most ineffective measure, according to Gocht et al. (2017), a fact also demonstrated by Vanni and Cardillo (2013) in a study conducted in Italy.

This study identified the agricultural area in the EU that was subject to greening, the number of farms that were targeted by one or more greening requirements, as well as the average payments paid to farmers and the cost incurred by farmers for the correct implementation of greening measures. A graphical representation of the number of holdings as well as the agricultural area subject to greening are highlighted in figure 1a and 1b.

As can be seen in figure 1a, out of total 150 million hectares, which represent the total agricultural area of the European Union, 129 million hectares made the object of Common Agricultural Policy and only 110 million hectares fall under the greening measures. A remarkable thing is that out of 10.2 million agricultural farms that exist at European Union level, about 6.8 million farms make the object of CAP and only 2.4 million farms fall under the greening project. This is analysed in figure 1b (European Court of Auditors, 2017). The difference between the share of holdings and the share of agricultural area results from the exemptions for small and organic holdings, but also for those who did not fill in the payment claims.

European Commission indicators reveal that 24% of farms were targeted for greening in 2015, totalling 73% of the EU’s agricultural area. A year later, this area increased to 77% (European Court of Auditors, 2017). However, these indicators contradict the studies by the JRC (cited in European Court of Auditors, 2017).

When the European Court of Auditors estimates that changes in farming practices were about 2% in 2017, the Joint Research Centre (JRC), as cited by European Court of Auditors (2017), reports changes of approximate 5% of EU agricultural area in farming practices after the first 2 years of greening was (European Court of Auditors, 2017). These changes and overlaps are shown in figure 2. As can be seen in figure 2, the total agricultural area of the European Union is covered by 60% with arable land, 34% with permanent meadows and 6% by permanent crops. The permanent crops are exempted from the application of greening process. Thus, changes were made to agricultural practices by 1.5%
for the areas occupied by permanent meadows and 4.2% for arable land. Out of total changes of 4.2% for arable land, 1.8% was observed in the crop diversification measures and 2.4% was observed by the introduction of areas of ecological interest (AEI)\(^6\). Initially, this project was larger, but they noted overlapping between the two measures: areas of ecological interest and the diversification of crops.

Both the Court of Auditors and Join Research Centre, as cited by European Court of Auditors (2017), indicate 4.5% increase of the EU agricultural area under farming practices following the implementation of the three greening measures. However, these data contradict the European Commission’s indicators which show an increase of 77% (European Court of Auditors, 2017). The huge difference between these two figures given by two different agencies can be explained on the basis of the way the two institutions have reported. Specifically, it depends on the calculation of the share of holdings targeted for greening in the total EU agricultural area and on the carry-over effect.

Regarding the share of targeted holdings, the European Commission, irrespective of whether a greening obligation concerns a single parcel or not, reports the area of the entire set of holdings. For example, if a farmer has 10 hectares of agricultural land (i.e., not subject to crop diversification or AEIs), of which only 1 hectare is covered by permanent grassland, the Commission considered the entire 10 hectares as being subject to greening, even though in reality only 1 hectare was subjected to greening measure, i.e. maintenance of permanent grassland.

Another negative contribution is the ballast effect, found in 4 out of 5 countries surveyed by the European Court of Auditors. Ballast effect refers to the overlap of greening with cross-compliance or management requirements. For example, in Poland, it was found that greening requirements were met before greening was introduced (hence it exceeded by 30%). Thus, in Poland, twice as many Areas of Ecological Interest (AEIs)\(^7\) were identified as required by greening.

\(^6\) AEIs - Areas of Ecological Interest, see also https://www.eca.europa.eu/Lists/ECADocuments/SR17_21/SR_GREENING_RO.pdf

\(^7\) https://www.eca.europa.eu/Lists/ECADocuments/SR17_21/SR_GREENING_RO.pdf
Crop diversification 1.8% Areas of Ecological Interest 2.4%
Overlap between areas of ecological interest and crop diversification 1.2%

| Permanent grassland (34% of EU agricultural area) – changes 1.5% | Crops exempted from greening (6% of EU agricultural area) |
| Arable land (60% of EU agricultural area) – changes 4.2% |

Figure 2: Changes in farming practices as a result of greening over the period of 2015-2017 [Source: European Court of Auditors (2017)]

The significantly reduced percentage of changes is also because the farms are considered green by definition and some are exempted from greening criteria. This category of farm holders includes small farmers, organic farms and farms with permanent crops. Farms with less than 10 ha of arable land are also exempted from crop diversification, and the introduction of green areas is for farms with more than 15 ha of arable land. The European Commission accepts these results, and, in explaining this, it also considers the maintenance of existing farming practices as a performance towards greening. According to Solazzo and Pierangeli (2016), changes in practices following the application of greening can be attributed mainly to farms in lowland areas. Cimino, Henke and Vanni (2015) claim that these changes are mainly found in farms specialised on monoculture. This fact is also supported by Helming and Tabeau (2018).

Research by Louhichi et al. (2018) demonstrate the reduced environmental benefits of greening. Similar studies showing reduced improvements in environmental indicators indicated the same (Cortignani, Severini and Dono, 2017; Solazzo, Donati and Arfini, 2015). A slight reduction in GHG emissions is observed in northern Italy, on an average by 0.2% (Gocht et al., 2017). This is also confirmed by Solazzo et al. (2016), who showed a decrease of 2% for CO₂, of 2.1% for NO₂ and of 0.4% for CH₄. Likewise, Pelikan, Britz and Hertel (2015) showed a 1.8% reduction in EU GHG emissions from greening. Other authors have also identified contributions of greening in reducing GHGs or improving soil structure (Walker et al., 2018; Cortignani and Dono, 2015). However, some authors have concluded that the cost-benefit ratio for these measures is unfair (Pe'er et al., 2017). Even if these environmental benefits are small, Ciliberti and Frascarelli (2015) are of the opinion that these policies can be a bridge to the next reform.

Poor climate outcomes are accompanied by similar outcomes in biodiversity. Brown et al. (2020) state in their study that common agricultural practices have
failed to maintain farmland biodiversity despite massive investments in greening subsidies. For example, between 1990 and 2020, bird and butterfly populations declined by 30%. The results provided by the European Court of Auditors in their report on biodiversity on arable land demonstrate that the CAP has not halted the decline of biodiversity on arable land (European Court of Auditors, 2020). The studies do not seek to highlight the inefficiency of the measures, but their reduced effectiveness (Gocht et al., 2017). In the view of Galán et al. (2015), greening needs to be rethought in order to achieve its environmental and climate targets.

Despite the reduced environmental benefits of implementing greening measures, the value of payments is very substantial. Payments to beneficiaries average €80/ha, while the costs of implementing greening are estimated to average €25-30/ha (European Court of Auditors, 2017). Therefore, the ratio between the subsidies offered to farmers by the implementation of greening and the expenses related to its implementation is unjustified. Thus, even if its purpose was to bring a higher complexity to the Common Agricultural Policy and to reward the farmers for the supply of green public goods, the greening remains, in essence, a payment scheme for enhancing incomes.

According to the JRC, quoted by the European Court of Auditors (2017), 71% of those targeted by at least one greening measure incurred no additional costs for implementation, while 29% of the remaining farmers incurred costs between €10 and €25 per ha. Of the farmers receiving subsidies for the implementation of greening, however, 2% incurred costs exceeding the subsidies, namely farms specialised in vegetable production. These activities generate high income. Similar results were obtained by Arfini, Donati and Solazzo (2013) in Italy, reporting an average expenditure of €21 per ha for the implementation of greening. The results provided by these authors may have a margin of error depending on the area analysed or the research model used in the study. The Court of Auditors answered all the questions in its 21/2017 report and concluded that greening is an ineffective scheme in terms of environmental benefits; the targets are not ambitious enough and are more of a direct payment to farmers, as most farms already met these requirements in the past (European Court of Auditors, 2017).

Referring to the changes brought about by the implementation of greening and the applicability of the measures provided for by it, also according to Majewski and Malak-Rawlikowska (2018), greening is not a complementary measure to the requirements of cross-compliance or environmental and climate measures, but a competing measure, in some cases overlapping with them. Instead, a notable performance of greening can be seen as banning the use of pesticides within areas of ecological interest, leading to a positive impact on biodiversity and the environment in general, including resource use.

The reduced benefits of greening are directly proportional to the legislative ambition of this reform. As can be seen in figure 3, the original proposal of the greening reform was much more ambitious than the version adopted and implemented during the period of 2014-2020. This is also supported by Vanni and Cordillo (2013). Concrete results are delivered by Solazzo et al. (2016), who show in a study the possibility of greenhouse gas reductions by 5% in case of adoption of the initial proposal, and reductions of only 1.5% for the properly implemented and enforced variant during the period of 2014-2020.
Crop diversification

Main crop <70%
Two main crops <95%
Of arable land and outdoor horticultural area

Prohibition to convert permanent grassland at farm level, except for maximum 5% of the area

Introduction of ecological interest areas, only non-production areas on 5% of arable land and permanent crops

Covering 70% of arable land, but also open-air horticultural area or permanent crops

Maintaining grassland

Main crop <70%
Two main crops <95%
Of arable land greater than 3 ha

Prohibition to convert permanent grassland at farm level, except for maximum 5% of the area

Introduction of ecological interest areas only of non-production areas and terraces on 7% of arable land and permanent crops

Introduction of ecological focus areas, both production and non-production, on 5% of arable land

ZIE

Main crop <75%
Two main crops <100%
Of arable land <10 ha

Prohibition to convert permanent grassland at farm level prohibited

Conversion of only PPSM grassland at farm level prohibited

Introduction of ecological focus areas, both production and non-production, on 5% of arable land

Topsoil

Covering 70% of arable land, but also open-air horticultural area or permanent crops

Assessment Initial proposal Final version

Practice The content of the requirements Relaxation of requirements Meeting the requirements Increase of the requirements Elimination of the requirements

Figure 3: Preliminary greening assessment, EC initial proposal and final form of greening adopted by the co-legislators for 2014-2020 [Source: European Court of Auditors (2017), according to legislation and impact assessment made in 2011 by the European Commission and according to the legislative proposal.]

In the case of maintaining permanent grassland, the starting point was to prohibit the conversion of all permanent grasslands to arable lands, except for a maximum of 5%. In the end, this measure is only applied to environmentally sensitive permanent grasslands (ESPG)\(^8\). Given that environmentally sensitive permanent grasslands cover 18% of the EU agricultural area and 96% of ESPG are located in Natura 2000 sites and subject to certain environmental rules, the climate and environmental benefits are roughly the same after greening. The ambition was also high in the original reform proposal for areas of environmental interest. The original requirements were to include non-productive nature

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\(^8\) [https://circabc.europa.eu/sd/a/981ee0af-d1c3-49a1-b770-02e29f7d45ab/Doc%20NADEG%202017-11-06%20Environmentally%20Sensitive%20Permanent%20Grasslands.docx](https://circabc.europa.eu/sd/a/981ee0af-d1c3-49a1-b770-02e29f7d45ab/Doc%20NADEG%202017-11-06%20Environmentally%20Sensitive%20Permanent%20Grasslands.docx)
conservation areas existing on 7% of the arable land or the area under permanent crops, but the legislation adopted also includes productive nature conservation areas, though only 5% and only on arable land. This measure can have high biodiversity benefits when choosing non-productive nature conservation areas, but lower benefits when choosing productive nature conservation areas.

Weakening the greening ambition during the legislative process leads to the continuation of income support without any particular environmental significance (Czekaj, Majewski and Was, 2013; Mahy et al., 2015). By implementing greening in the adopted form, no remarkable environmental results can be achieved because there are no point targets and they are not ambitious enough (Diotallevi et al., 2015; Kirchner, Schönhart and Schmid, 2016; Louhichi et al., 2018).

For greening to bring considerable benefits, investment in research is needed to identify and adopt the most effective measures through the Common Agricultural Policy (Singh, Marchis and Capri 2014). The lack of linkage of policy decisions with research in the latest reform is reflected in the absence of binding measures such as greening in the livestock sector as well. This sector is a large generator of greenhouse gases and environmental actions in this regard need to be applied at source. The agro-ecological approach can be a key factor in reducing fertilisers and pesticides, and preserving biodiversity, which is a primary objective for the next reform guided by the principles of the European Green Pact9 (Maxim, 2019).

A new green architecture during the period of 2021-2027

With the experience of the reform that has just ended in 2020, a new reform is needed that retains the strengths of the past, but also makes further improvements. The future Common Agricultural Policy for the period of 2021-2027 continues to build on the two pillars and proposes a new green architecture with even more emphasis on agro-ecological practices. Cross-compliance and greening, components of Pillar I, will merge into a new system called cross-compliance, plus new environmental eco-schemes. Pillar II, as in the past, will include voluntary environmental measures as well as rural development measures.

The new reform aims at greener farming with fewer pesticides, protection of wetlands and peatlands, more organic farmland, and the implementation of new environmental eco-schemes. Under the new requirements, agroecology will be the basis for implementing the new policies, and each farm will allocate 3% of its arable land to biodiversity areas, ensuring that farmers can be rewarded for reaching the 7% threshold.10

Following the model of the recently concluded reform, the requirements of the original proposal put forward by the European Commission for the forthcoming reform, as well as the budget, were substantially reduced during the legislative process. It was also proposed to reduce cumulative subsidies for various measures and paid from the CAP budget (€60,000- €100,000 per farm), which would have avoided over-funding of large farms.11 This measure was subsequently

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10 In this case, these are proposals from the European Commission, and nothing is approved. There are discussions for the new common agricultural policy. Each Member State will draw up a national strategic plan.
11 In this case, these are proposals from the European Commission, and nothing is approved. There are discussions for the new common agricultural policy. Each Member State will draw up a national strategic plan. It was a proposal that was abandoned.
dropped. Thus, there is still a risk of small farms disappearing, in addition to the 4 million small farms that have disappeared in the last 10 years due to the misapplication of agricultural policies.

The final version of the legislative proposal accepted by the co-legislators foresees that 20% of direct payments during the period of 2023-2024 and 25% between 2025 and 2027 will be allocated to eco-schemes and at least 35% of Pillar II will be directed to environmental and climate measures.12

For the implementation of the next reform, each Member State will create a National Strategic Plan (NSP). This will be drawn up after consultation with the country’s farmers, in line with the objectives proposed by the European Green Deal 2030, the EU Biodiversity Strategy 203013 and the Farm to Fork Strategy14. This plan will enter into force after its submission to and approval by the European Commission, with a transition period between 2021 and 2023. The implementation of the whole reform will take place during the period of 2023-2027.

4. Conclusions

The latest reform of the Common Agricultural Policy has tried to put a strong emphasis on environmental protection by introducing greening and has been running over the period of 2014-2020. At the end of it, the European Commission delivers high results showing a greening coverage of 73% of the EU agricultural area after the 1st year of implementation, and after 2nd year it increases to 77%. The Commission’s result indicators are at odds with the parallel studies. While the European Court of Auditors estimates changes in farming practices of around 2% only, the Join Research Centre reports the changes of 4.5%. The changes reported by the Join Research Centre are bifurcated as 1.8% for crop diversification, 2.4% for ecological focus areas and 1.5% for permanent grassland. The difference of 1.2% is due to overlaps between the three measures. The discrepancy between the data provided by the European Court of Auditors and Join Research Centre is due either to different survey methods or to the areas surveyed. Contrary to the low efficiency of greening, the payments made are on an average 80 €/ha while the costs incurred for implementing greening are on an average 25-30 €/ha. Moreover, 71% of farmers incurred no additional costs for implementing greening.

Due to the lack of linking policy decisions with research in the adoption of Common Agricultural Policy, we are now in a situation where 80% of subsidies go to 20% of beneficiaries, 4 million small farms have disappeared in the last 10 years, and half of Europe’s agricultural land is owned by 3% of farmers. In contrast to these losses, problems still persist and the progress on environmental and climate indicators is quite slow.

Aimments in agriculture to care for the environment and climate should be realised through the new architecture of merging cross-compliance and greening into a system called cross-compliance, to which the new eco-schemes and other

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12 It is a minimum percentage that must be allocated. Each Member State will decide how to do this. There are discussions for the new common agricultural policy. This aspect will be the subject of future research, after the creation of national strategic plans.
climate and environment-friendly measures will be added. The European Green Deal aims to reduce the use of pesticides by 50%, fertilisers by 20% and antimicrobials by 20% by 2030. Another major goal is to have 25% of the EU's agricultural area farmed organically. Analysing these targets against the measures outlined, it is highly unlikely that these targets will be met, as the new green architecture is left to Member States, who, with the experience of previous reform, will offer farmers menu-style measures. The new reform will take effect from 2023 because the new measures and eco-schemes are not finalised.

5. References


Author’s Declarations and Essential Ethical Compliances

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Enhancing Farmers’ Seed Systems through Empowerment of Women: A Case Study from China

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Abstract
Maintaining farmer’s seed systems is important to secure the adaptive capacity both ecologically and socially for global food systems, and to secure genetic diversity. In a mountain village of southwest China, a Participatory Action Research Team has carried out action research for more than 20 years to support women's participation in participatory breeding and to enhance the farmers’ seed system. In this case study, the team assisted women in the conservation of local varieties and establishment of community seed banks to enhance farmers’ seed systems. The women-led agricultural cooperatives promoted the economic development of the community and improved the sustainability of farmers’ seed system through eco-circular agriculture and the community supported agriculture (CSA) model. In this participatory process, the empowerment of women improved women’s comprehensive ability and provided the guarantee of human resources for enhancing farmers' seed system. Multi-stakeholder processes also extended important support to this model work.

Keywords
Seed bank; Farmers’ network; Participatory action; Community agriculture

1. Introduction

Maintaining farmer’s seed systems contributes to securing the adaptive capacity both ecologically and socially for global food systems, and to securing genetic diversity. A wide range of local varieties, through years of selection and optimization by farmers, possess strong resistance to risks. It is crucial to explore effective pathways to enhance farmers’ seed system under the current pressure of the commercialization of seeds and market monopoly. In this article, one example from Guangxi, China is presented; it incubates changes to enhance the farmers’ seed system through women empowerment process.

Over the past half-century, the commercialization of seeds driven by the Green Revolution has led to the abandonment of local crop varieties, leading to a 75% loss of genetic diversity worldwide (Xu et al., 2012). In China, the number of local varieties of major food crops observed 71.8% decrease, from 11,590 in 1956 to 3,271 in 2014 (Liang, 2018).
Being one of the most biologically- and culturally diverse provinces of China, Guangxi also belongs to the ecologically fragile region due to its widespread karst mountainous rocks. Environmental constraints are coupled with social issues such as poverty and feminization of agriculture. Conserving the rich germplasm resources of farming families, improving the fragile ecosystems and achieving a local development present challenge. Solutions with a feature of joint development of nature and people could inform those who rely on mountainous areas for their livelihood and well-being, which accounts for approximately 12% of the global population (Xu, 2018).

![Photo 1: A view of Guzhai Village (Photo by Qiubi)](image)

The Participatory Action Research Team (hereafter referred to as "the Project Team") of the Chinese Academy of Sciences coordinated the implementation of a series of interventions including participatory plant breeding (PPB) in 6 villages in Guangxi province, and Guzhai Village was one of those 6 villages. One of the objectives of the interventions was to strengthen farmers' seed systems through empowering farmers, especially women farmers as they are the dominant labour forces in farming as men migrate to cities for wage earning jobs. All activities were implemented in multidisciplinary collaborations with the research institutes at both national and provincial levels, such as the Chinese Academy of Agricultural Sciences (CAAS) and the Guangxi Academy of Agricultural Sciences (GAAS), and with strong support from the local authorities. Involvement of private sector and local NGOs were also very important to the success of the project.

2. Conservation of Local Varieties

2.1. Improvement, selection and technology dissemination of local varieties:

Women have been breeding traditional crop varieties since the beginning, ensuring the continuation and development of local maize, soybean and other
crops, and working with outside specialists on PPB trials to produce new varieties. The Project Team coordinates frequent visits from domestic and international experts for knowledge sharing and capacity building in this regard. Meanwhile, good experiences and knowledge are also shared with other villages through the farmer’s seed network.

Photo 2: A farmer seed fair at Guzhai Village (Photo by Simon Lim)

Photo 3: Farmer’s participatory evaluation of Maize PPB&cPVS trial (Photo by FSN)
2.2. Community seed bank:

In 2006, the preliminary resource registry began documenting both the biological and cultural heritages of the communities with texts and pictures, which were to be the vehicles for sustainable nature-community development. The foundation of the Community Seed Bank (CSB) in 2018 marks a new era for the sustainable usage of natural resources. Like the thousands of CSBs found in over 20 countries, it started out a self-managed entity aimed at strengthening the local seed system. But it grew in size soon and linked up with government germplasm banks and other institutions, which makes it possible for local varieties to be preserved and disseminated at much larger scales. Today the community seed bank has 124 local varieties in its registry and 63 local varieties in its physical inventory. It is a source for the diverse ecological vegetable production, which is now the community’s main industry.

Photo 4: LU Rong-Yan examines seeds in the Community Seed Bank (Photo by Qiubi)

3. From Conservation to Community Development

3.1. Eco-circular agriculture and the CSA model:

Around 2008, as people’s awareness for ecological environmental protection and food safety rose, the Project Team introduced Farmers’ Friends (a local NGO) and the Community Supported Agriculture (CSA) model in Guzhai village. Gradually, the Project Team created the "maize—pig—vegetable" eco-circular agriculture model. The wide adoption of eco-circular methods improved the local environment and led to the direct supply of their vegetables to an organic restaurant in Nanning City.
3.2. The women-led agricultural cooperatives:

From the initially established women’s group to an officially registered professional cooperative, the scale has grown three-fold since its hatch, receiving continued support from external parties and multiple levels of the government. The Cooperative has nearly 100 households, with women a backbone of the Cooperative, accounting for 85% of its working members. Its total annual income is expected to rise to approximately 1.57 million yuan (equivalent to 0.23 million USD) in 2020, with an average annual household income of 15,000 yuan (or USD 2225). At the same time, the Cooperative actively assumes social responsibility to alleviate poverty and encourages the inclusion of poor households. It also facilitates a better comprehension of an eco-friendly and healthy way of production and life.

4. The Ways Forward

4.1. Multidisciplinary and multi-level participation:

Under the coordination of the Project Team, links were established between communities and different levels of research institutions, civil society organizations, hotels, government agricultural extension services, etc. The involvement and support of local governments has also played an important role in the process. Not only was it an important means of strengthening farmers’ seed systems, but the resources also pulled by having stakeholders at various levels made it possible for the Cooperative, which is a special form of enterprise to adapt to the rural communities. The diversified and integrated development of farmers’ cooperatives can become an important rural development path in China.

4.2. Empowerment of women:

In the process of the development, the Cooperative leader, once an ordinary rural woman has now become a pillar of the community. The process also
strengthens the leadership and social and economic empowerment of rural women, awakens the ordinary sense of ownership of rural women, whose overall capacity to contribute to and benefit from the sustainable development of their communities is enhanced.

Photo 6: Local seed passed down through generations (Photo by Qiubi)

4.3. Policy advocacy:

The Project Team translated the results of the research into policy through dialogues, proposals and media publicity. Project Team also submitted policy proposals to the multiple levels of government agencies through different channels, calling for the promotion of the healthy development of farmers’ seed systems in China, enhancing the influence of farmers’ seed systems through multi-faceted crossover cooperation platforms, promoting agricultural biodiversity conservation, and making long-term strategic reserves for food security.

5. Conclusion

From the participatory breeding activities in 2000 to the sustainable use of agrobiodiversity, the farmers’ seed system in the community has been enhanced and developed sustainably in the whole process. In the process of participatory action research, strengthening rural women's leadership, comprehensive ability and breeding technology has awakened women's sense of ownership, and improved their overall ability to strengthen farmers' seed system and women's benefit from it. Under the coordination of the participatory action research project team, the community has established cooperative relations with multiple institutions, and the diversified support has played an important role in women's empowerment, strengthening farmers' seed system and policy advocacy.
6. References


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Aim & Scope

The objective of our journal "Agrobiodiversity & Agroecology" is to explore variety of concepts, practices and implications in emerging scientific fields within combined and integrated domain of Agrobiodiversity (or Agricultural Biodiversity) and Agroecology. This journal aims at creating an opportunity for presenting different research from all parts of the world that facilitate the dialogue across different disciplines and various actors for capitalizing on different kind of knowledges.

What is Agrobiodiversity?
As described by UN Convention on Biological Diversity (CBD), "the Agricultural biodiversity is a broad term that includes all components of biological diversity of relevance to food and agriculture, and all components of biological diversity that constitute the agricultural ecosystems. Also named agro-systems; the variety and variability of animals, plants and micro-organisms, at the genetic, species and ecosystem levels, which are necessary to sustain key functions of the agro-ecosystem, its structure and processes. Agricultural biodiversity is the outcome of the interactions among genetic resources, the environment and the management systems and practices used by farmers. This is the result of both natural selection and human inventive developed over millennia. CBD expands the following dimensions of agricultural biodiversity:

1) Genetic resources for food and agriculture
2) Components of biodiversity that support ecosystem services
3) Biotic factors
4) Socio-economic and cultural dimensions.

What is Agroecology?
Agroecology is an applied science that studies ecological processes applied to agricultural production systems. Bringing ecological principles to bear can suggest new management approaches in agroecosystems. Agroecologists study a variety of agroecosystems. The field of agroecology is not associated with any one particular method of farming, whether it be organic, regenerative, integrated, or conventional, intensive or extensive, although some use the name specifically for alternative agriculture. Agroecology is defined by the OECD as "the study of the relation of agricultural crops and environment." Agroecology is a holistic approach that seeks to reconcile agriculture and local communities with natural processes for the common benefit of nature and livelihoods. Agroecology is inherently multi-disciplinary, including sciences such as agronomy, ecology, environmental science, sociology, economics, history and others. Agroecology uses different sciences to understand elements of ecosystems such as soil properties and plant-insect interactions, as well as using social sciences to understand the effects of farming practices on rural communities, economic constraints to developing new production methods, or cultural factors determining farming practices. The system properties of agroeco systems studied may include productivity, stability, sustain ability and equatability.

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