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Studies on functional components of apple-based agroforestry system in Mandi district of the wet temperate region of Himachal Pradesh

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Abstract
The present investigation entitled Apple-based agroforestry systems of wet temperate region of district Mandi was carried out for two consecutive years 2021-2022 and 2022-2023. The study area was divided into four altitudinal zones as A_1 (1500-1800 m), A_2 (1801-2100 m), A_3 (2101-2400 m) and A_4 (2401-2700 m). In each altitudinal zone, 3 villages were randomly selected and within each villages 15 farmers were selected and categorised as marginal, small and semi-medium on the bases of their land holding. A total of 180 households were surveyed and interviewed. The results revealed that the farmers were cash crops like *Zea mays*, *Brasssica oleracea* var. *capitata*, *Vigno mungo*, *Phaseolus vulgaris*, *Solanum tuberosum*, *Pisum sativum*, *Hordeum vulgare*, *Triticum aestivum* as a cash crops and *Amaranthus caudatus*, *Eleusin coracana*, *Chenopodium album* as the traditional crops under apple based agroforestry system. They also retained the grasses like, *Chrysopogon gryllus*, *Dactylis glomerata*, *Chrysopogon montanus*, *Digitaria stricta*, *Dichanthium annulatum*, *Themeda anathera*, *Cynodon dactylon*, *Festuca arundinacea*, *Desmostachya binnata*, *Bothriochloa pertusa*, *Cynodon dactylon* and *Bromus inermis* etc.

Keywords: Agriculture crops, agroforestry, apple-based system, functional component, farmer category

Introduction
Agroforestry is a significant climate-smart agriculture approach, integrating sustainable production with climate change adaptation and mitigation (Vaast *et al*., 2016) [24]. Horticulture-based agroforestry play a diverse role in agricultural production and environmental protection by sequestering carbon to address ongoing climate change concerns, ultimately enhance human well-being is always recommended. A well-suited combinations of tree and crop species to minimize resource competition and maximize resource utilization (Pardon *et al*., 2018) [14]. Therefore, the primary aim of the research was to discuss the Apple-based agroforestry systems, highlighting their benefits in local production system and livelihood of the local people.

Himachal Pradesh, being a hilly state of Indian Himalayas, exhibits vast agrioclimatic conditions due significant altitude variation in altitude ranging from 300 m to 6,530 m above sea level. This topographical diversity leads to the differences in land characteristics, including pH levels, fertility, soil structure, as well as slope/aspect and rainfall patterns. These varied ecological conditions foster rich plant biodiversity, enabling the cultivation of diverse agricultural crops. Apple-based agroforestry systems have received limited attention in global research, particularly regarding the quantification of biophysical interactions between fruit trees and crops. In wet temperate regions of H.P., apple based agroforestry systems are prevalent. Apples is one of the leading fruit crops worldwide, predominantly thriving in temperate agro-climatic zones. This crop contribute approximately half of the global production of deciduous fruit trees and serve as a significant cash crop for farmers (Ashebir *et al*., 2010; Ntakyo *et al*., 2013, Kebede and Behailu, 2018) [1, 13, 9].

In traditional agriculture system the basic food requirement of local people is fulfilled by growing agricultural crop as sole crop or with other agroforestry trees produces fiber, fruit, food and fuelwood. Apples, now regarded as a primary cash crop and are often intercropped with vegetables and pulses through innovative agroforestry practices.

Farmers in these region have created unique agroforestry systems that blend traditional agricultural methods with modern apple cultivation techniques. These systems play a vital role in enhancing biological diversity productivity, improve environmental benefits, and promote carbon sequestration.

The present study aimed study the apple-based agroforestry system in Himachal Pradesh, India and highlight its economic significance among the local farmers. The research aims to evaluate agroforestry systems under different altitudinal zones and it influence on the farmers. It targets marginal, small, and semi-medium holder farmers, focusing on the intercropping of crops/grasses with apples.

Materials and Methods

Study area

The present study was carried out in Mandi district of Himachal Pradesh. It is situated at coordinates 31° 42′ 25″ N latitude and 76° 55′ 54″ E longitude. The elevation within the district varies, ranging from 450 meters to 4800 meters above sea level. The winter season from November to February, while the summer season extends from March to June. The monsoon occurs from July to the end of September, with recorded average annual rainfall ranging from 1516.1 mm in 2021 to 1617.3 mm in 2022. During the summer months, average temperature ranges from 16.0 °C to 35.0 °C, while winter temperature lies between 1.1 °C and 21.6 °C. The study area lies under the wet temperate agro-climatic zone, contributing to its diverse ecological characteristics.

Sampling procedure

A comprehensive survey on the wet temperate (WT) region, was undertaken in Mandi districts of Himachal Pradesh for assessment of Apple-based agroforestry systems. Four altitudinal zones were delineated in each district and three villages were randomly selected in each of the altitudinal zones and then noted down and divided into four different altitudinal zones as given below

Table: 1: The details of Altitudinal Zonation and selected villages in Mandi district of Himachal Pradesh

Sr.no	Altitudinal Zones	Altitudinal range (m)	Selected Villages
1	A_1	1500-1800 m	Dobrot, Mahunag, Churag
2	A_2	1801-2100 m	Bulas, Aukal, Pandoh
3	A_3	2101-2400 m	Baila, Ruhada, Raindhar
4	A_4	2401-2700 m	Riyara, Dhalyar, Janoot

A systematic study was conducted to explore the agricultural practices across different altitudinal zones. Within each selected village, 15 farmers were selected and then categorized into three groups: marginal, small, and semi-medium farmers on the basis of their land holdings. The multistage sampling approach was adopted for the collection of comprehensive field data and included a total of 180 farmers.

Table 2: The category of the farmers and their operational land holding

Sr.no	Farmers categories*	Size of operational land holding
1.	Marginal	<1 ha
2.	Small	1-2 ha
3.	Semi-medium	2-4 ha

*Government of Himachal Pradesh

Identification of existing apple-based agroforestry systems

The agroforestry systems present in the study area were categorised based on their structural characteristics; namely the nature and arrangement of components well as their functional aspects, which include the roles and outputs of these components, following the framework suggested by Nair (1985) [12]. In each agroforestry system, specific system units were identified, as per Zou and Sanford (1990) [27]. These system units were classified based on the key functional elements that are paired with particular tree species or related components like; food grains, includes vegetables, and pulses; horticultural components included specific fruit trees.

The type of Agroforestry system primary or secondary were identified after analyzing its structure and the specific functions of its components.

Primary component

The components, which occupied the larger area of the total unit area and serve the major function *i.e.* production of the primary out needed by the villagers.

Secondary component

The components, which occupied the relatively the lesser area of the total unit area compared to component and yielding the secondary outputs needed by the villagers.

On the base of above classification apple-based agroforestry system is classified in two types under different farmer's category as below

1. **Horti:** Agriculture system
2. **Horti:** Pasture system

Results

The results revealed that in Mandi district the farmers utilized diverse agroforestry systems across the various altitudinal zones studied *viz.*, A_1 (1500-1800 m), A_2 (1801-2100 m), A_3 (2101-2400 m) and A_4 (2401-2700). These classifications include both primary and secondary components of the study. The Primary Components were large and crucial for producing essential outputs to meet the primary needs of the villagers, highlighting their importance to the community. Secondary components, while smaller, but also provide valuable outputs that address additional community needs and support the primary components, enhancing the overall efficiency and effectiveness of the system.

Altitudinal Zone-I

At an altitude of 1500-1800 meters, the villages of Dobrot, Mahunag, and Churag showed Horti-agriculture agroforestry system which integrated horticulture with agriculture, allowing for a diverse range of crops to be cultivated. In the agricultural landscape, different farmer categories practice varied cropping strategies based on the season. Marginal farmers focus on cultivating a range of crops during the Kharif season, including *Capsicum annuum* (bell pepper), *Allium sativum* (garlic), *Raphanus sativus* (radish), *Spinacia oleracea* (spinach), and *Allium cepa* (onion). They also grow *Hordeum vulgare* (barley) and *Triticum aestivum* (wheat) in the Rabi season. Small farmers, on the other hand, tend to grow crops such as *Zea mays* (maize), *Linum usitatissimum* (flax), *Phaseolus vulgaris* (common bean), *Brassica oleracea* (cabbage), *Solanum melongena* (eggplant), and *Pisum sativum* (pea) with *Malus×domestica* (apple) during the Kharif season (Fig.1). In the Rabi season, they primarily cultivate *Triticum aestivum* and *Hordeum vulgare*. Similarly, semi-medium farmers intercropped during the Kharif season, the like *Allium sativum*, *Zea mays*, *Phaseolus vulgaris*, *Solanum tuberosum* (*potato*), *Pisum sativum*, and *Brassica oleracea* with *Malus×domestica*. In the Rabi season, *Pisum sativum* and *Triticum aestivum*, were grown (Table 1).

The apple-based horti-pasture system showed a diverse array of grasses in various farmers orchards. Within the horti-pasture agroforestry system, marginal farmers cultivated *Cymbopogon martini*, *Aundinella nepalensis*, *Setaria glauca*, and *Andropogon nardus*. In contrast, small farmers have a broader variety, which consists of *Aundinella nepalensis*, *Setaria glauca*, *Desmostachya binnata*, *Cymbopogon martini*, *Bothriochloa pertusa*, *Chrysopogon gryllus*, *Imperata cylindrica*, *Dactylis glomerata*, *Saccharum spontaneum*, and *Cynodon dactylon*. Furthermore, the semi-medium farmer category emphasized the presence of these grasses specifically under the *Malus* × *domestica* species (Table 2).

Altitudinal zone-II

The altitude zone II (1801-2100 m) encompasses the villages; Bulas, Aukal, and Pandoh. A diverse range of agriculture crops with horticultural crops were cultivated, varying as per season and farmer category. Semi-medium farmers primarily intercropped with *Pisum sativum* (pea), *Zea mays* (maize), *Vigna mungo* (black gram), *Phaseolus vulgaris* (common bean), *Solanum tuberosum* (potato), and *Cucurbita pepo* (pumpkin) in Kharif season. In the Rabi season, *Pisum sativum*, *Hordeum vulgare* (barley), and *Triticum aestivum* (wheat) with *Malus* × *domestica* (apple).

Fig 1: System unit of Horti-agriculture Apple based Agroforestry System in Mandi district

Small-scale farmers also grows agricultural diversity by cultivating a variety of crops during the Kharif season, including *Brassica oleracea* (cabbage), *Zea mays*, *Vigna mungo*, *Phaseolus vulgaris*, *Solanum tuberosum*, *and Linum usitatissimum* (flax). During the Rabi season, *Hordeum vulgare* and *Triticum aestivum* were intercropped with *Malus* × *domestica*. Marginal farmers grows crops like *Solanum tuberosum*, *Colocasia esculenta* (taro), *Solanum melongena* (eggplant), *Brassica oleracea* var. *italica* (broccoli), *Hordeum vulgare*), as well as *Triticum aestivum* with *Malus* × *domestica*, in both the Kharif and Rabi seasons (Table 1).

In horti-pasture system, the marginal farmers primarily cultivated crops such as *Chrysopogon gryllus*, *Apluda mutica*, *Setaria glauca*, and *Chrysopogon montanus*. In contrast, small farmers included grasses such *as Dactylis glomerata*, *Brachiaria mutica*, *Avena sativa*, and *Andropogon nardus* in their agroforestry practices. For semi-medium farmers, the grass species observed comprised *Dactylis glomerata*, *Brachiaria mutica*, *Avena sativa*, *Andropogon nardus*, and additionally *Heteropogon contortus* (Table 2 & Fig. 2).

Table 1: Functional components of Apple-based agroforestry system among farmers categories in different altitudinal zones of Mandi district (H.P)

Horti-agriculture system					
Tree species			**Agriculture crops**		
Age of fruit tree	**Density (per ha)**	**Average holding (ha)**	**Kharif**	**Rabi**	**Net cropped area (ha)**
Altitudinal zone-I (1500-1800 m)					
Marginal					
Malus× domestica (~12yr)	233	0.60	*Capsicum annuum, Allium sativum, Raphanus sativus, Spinacia oleracea, Allium cepa*	*Hordeum vulgare, Triticum aestivum*	0.40
Small					
Malus× domestica (~12yr)	250	0.70	*Zea mays, Linum usitatissimum, Phaseolus vulgaris, Brasssica oleracea, Solanum melongena, Pisum sativum*	*Triticum aestivum, Hordeum vulgare*	0.30
Semi-Medium					
Malus× domestica (~14yr)	266	0.70	*Allium sativum, Zea mays, Phaseolus vulgaris, Solanum tuberosum, Pisum sativum, Brasssica oleracea*	*Pisum sativum, Triticum aestivum*	0.30
Altitudinal zone-II (1801-2100 m)					
Marginal					
Malus× domestica (~16yr)	233	0.60	*Solanum tuberosum, Colocasia esculenta, Capsicum annuum, Allium sativum, Cucurbita pepo*	*Hordeum vulgare, Triticum aestivum*	0.40
Small					
Malus× domestica (~18yr)	250	0.65	*Brasssica oleracea, Zea mays, Vigno mungo, Phaseolus vulgaris, Solanum tuberosum, Linum usitatissimum*	*Pisum sativum, Hordeum vulgare, Triticum aestivum*	0.35
Semi-Medium					
Malus× domestica (~18yr)	266	0.70	*Pisum sativum, Zea mays, Vigno mungo, Phaseolus vulgaris, Solanum tuberosum, Cucurbita pepo*	*Pisum sativum, Hordeum vulgare, Triticum aestivum*	0.30
Altitudinal zone-III (2101-2400 m)					
Marginal					
Malus× domestica (18~yr)	233	0.70	*Pisum sativum, Zea mays, Vigno mungo, Phaseolus vulgaris, Capsicum annuum*	*Pisum sativum, Hordeum vulgare, Triticum aestivum*	0.30
Small					
Malus× domestica (~20yr)	266	0.75	*Pisum sativum, Zea mays, Vigno mungo, Phaseolus vulgaris, Solanum tuberosum, Allium sativum*	*Pisum sativum, Hordeum vulgare, Triticum aestivum*	0.25
Semi-Medium					
Malus× domestica (~20yr)	283	0.75	*Pisum sativum, Zea mays, Phaseolus vulgaris, Vigno mungo, Solanum tuberosum*	*Pisum sativum, Hordeum vulgare, Triticum aestivum*	0.25
Altitudinal zone-IV (2401-2700 m)					
Marginal					
Malus× domestica (~14yr)	233	0.60	*Solanum tuberosum, Colocasia esculenta, Vigno mungo, Pisum sativum, Zea mays*	*Pisum sativum, Hordeum vulgare, Triticum aestivum*	0.40
Small					
Malus× domestica (~14yr)	266	0.65	*Pisum sativum, Zea mays, Phaseolus vulgaris, Vigno mungo, Solanum tuberosum*	*Hordeum vulgare, Triticum aestivum*	0.35
Semi-Medium					
Malus× domestica (~15yr)	250	0.70	*Pisum sativum, Zea mays, Phaseolus vulgaris, Vigno mungo, Solanum tuberosum*	*Pisum sativum, Triticum aestivum*	0.30

Fig 2: System unit of Horti-pasture Apple based Agroforestry System in Mandi district

Altitudinal zone-III

In the altitudinal zone ranging from 2101 to 2400 meters, Baila, Ruhada, and Raindhar villages were selected to explore the diversity in cropping patterns based on farmers land holdings. The semi-medium farmers were practising a varied intercropping system. During the Kharif season, they cultivate a variety of crops including *Pisum sativum* (peas), *Zea mays* (maize), *Phaseolus vulgaris* (common beans), *Vigna mungo* (black gram), and *Solanum tuberosum* (potatoes). In Rabi season, these farmers primarily grow *Pisum sativum*, *Hordeum vulgare* (barley), and *Triticum aestivum* (wheat), often alongside *Malus domestica* (apple trees) Table 1.

Small farmers, on the other hand, intercropped various species with *Malus domestica* during the Kharif season, including *Pisum sativum*, *Zea mays*, *Vigna mungo*, *Phaseolus vulgaris*, *Solanum tuberosum*, and *Allium sativum* (garlic). In Rabi season, the crops like *Pisum sativum*, *Hordeum vulgare*, and *Triticum aestivum* were cultivated. The Marginal farmers also showed a diverse cropping pattern. In the Kharif season, they were cultivating *Pisum sativum*, *Zea mays*, *Vigna mungo*, *Phaseolus vulgaris*, and *Capsicum annuum* (bell peppers), while focusing on *Pisum sativum*, *Hordeum vulgare*, and *Triticum aestivum* in Rabi season with *Malus domestica* as intercrop.

Farmers in this region have retained various types of grasses for use as fodder, particularly in apple orchards. Among marginal farmers, the notable grass species include *Dactylis glomerata*, *Chrysopogon gryllus*, *Chrysopogon montanus*, *Digitaria stricta*, and *Dichanthium annulatum*. In the small farmers category, the grasses observed are *Dichanthium annulatum*, *Chrysopogon montanus*, *Chrysopogon gryllus*, *Themeda anathera*, *Cynodon dactylon*, *Festuca arundinacea*, *Dactylis glomerata*, and *Desmostachya binnata*. Semi-medium farmers have access to a diverse array of grasses as well, including *Dichanthium annulatum*, *Dactylis glomerata*, *Bothriochloa pertusa*, *Cynodon dactylon*, *Chrysopogon montanus*, and *Bromus inermis*, all of which grow under the apple variety *Malus× domestica* (Table 2).

This diversity in cropping patterns showcases the adaptive strategies employed by farmers, which are influenced by their land holdings and the varying altitudinal conditions of the area.The variety of grasses presented underscores the significance of diverse fodder sources in promoting sustainable farming practices within the region.

Altitudinal zone-IV

A altitude ranging from 2401 to 2700 m in the villages; Riyara, Dhalyar, and Janoot. Under the horti-agriculture system, marginal farmers were primarily cultivating *Solanum tuberosum* (potato), *Colocasia esculenta* (taro), *Vigna mungo* (black gram), *Pisum sativum* (pea), and *Zea mays* (maize) during the Kharif season. In the Rabi season, they grow *Pisum sativum*, *Hordeum vulgare* (barley), *Triticum aestivum* (wheat), along with *Malus × domestica* (apple). Small farmers, often intercropped *Pisum sativum*, *Zea mays*, *Phaseolus vulgaris* (common bean), *Vigna mungo*, and *Solanum tuberosum* in Kharif, while cultivating *Hordeum vulgare* and *Triticum aestivum* in the Rabi season with apple. Semi-medium farmers grows *Pisum sativum*, *Zea mays*, *Phaseolus vulgaris*, and *Vigna mungo* during Kharif. *Pisum sativum* and *Triticum aestivum* were predominant in Rabi season under *Malus × domestica* (Table 1).

In Horti-pasture agroforestry system, the grass species varied among the different categories of farmers (Table 2). For marginal farmers, the most common grasses were *Dactylis glomerata*, *Chrysopogon montanus*, *Chrysopogon gryllus*, *Dichanthium annulatum*, *Cynodon dactylon*, and *Poa annua*. Small farmers tended to favour *Chrysopogon montanus*, *Chrysopogon gryllus*, *Dichanthium annulatum*, *Cynodon dactylon*, *Festuca arundinacea*, *Poa annua*, and *Dactylis glomerata*. In the case of semi-medium farmers, the prevalent grass species were *Digitaria stricta*, *Chrysopogon gryllus*, *Setaria glauca*, *Chrysopogon montanus*, and *Poa annua*, often found in association with *Malus × domestica*.

Discussions

In temperate regions, it was observed that farmers cultivate a variety of agricultural and grasses beneath apple trees. Several key factors influence the diversity in cropping patterns among different categories of farmers. In the present study, it was observed that farmers in the Mandi district of Himachal Pradesh were cultivating a variety of crops alongside apple trees. Notable crops include Allium cepa, Allium sativum, Cucurbita pepo, Phaseolus vulgaris, Pisum sativum & Brassica oleracea etc. These crops serve as cash crops within the horticultural system established around apple trees. Similar findings regarding cropping patterns under apple trees have been documented in previous research by Kumari *et al*. (2008) [10], Rajput (2010) [19], Singh (2019) [22], Kapoor (2020) [8], Janju (2021) [7], and Sharma (2022) [21] in the region of Himachal Pradesh.

Recent research indicated that farmers in Mandi are actively engaged in agri-horticulture and horti-pasture agroforestry practices. These systems integrate various elements, including fuel wood, fruit trees, agricultural crops, shrubs, and herbs. This multifaceted approach enhances both ecological diversity and the economic viability of traditional agroforestry practices. In the current study, a total of 17 different agricultural crops and 21 grass species were found to be cultivated at different altitudinal zones by the framers of all categories, with apple. Sahoo (2009) [20] also documented a remarkable diversity of crops in the region, with a total of 231 species identified, which includes 50 shrubs, 76 herbs, and 105 trees across 88 families. Such findings provide valuable insights into tree diversity within agroforestry systems. These insights are consistent with the work of Bijalwan and Dobriyal (2016) [3], who studied the tree diversity in Uttarakhand. Their research showcased a rich variety of tree species, identifying 13 species in agri-silviculture systems, 16 species in agri-silvi-horticulture systems, and 8 species in agri-horticulture systems. Additionally, Phondani *et al*. (2017) [16] emphasized the importance of indigenous trees in agroforestry, listing 30 species that thrive at elevations of 800-1800 meters in Uttarakhand. These trees provide essential resources for local communities, including fodder, food, fuelwood, medicine, timber, fiber, dye, and cosmetics. Umrao *et al*. (2017) [23] further enriched the understanding of species diversity by analyzing 32 species in both agri-silviculture and agri-horticulture systems. Together, these studies highlight the ecological and socioeconomic significance of tree diversity, reinforcing the numerous benefits that agroforestry practices can offer.

Recent studies also highlight the unique agricultural dynamics in the A1 altitudinal zone of the Mandi district, revealing that this area boasts a higher number of functional components compared to other altitudinal zones, namely A2, A3, and A4. Specifically, the A1 zone supports 13 distinct functional components, which is attributed to the region's larger population of farmers who significantly depend on agriculture for their livelihoods. This dependence encourages the cultivation of a diverse array of crops, enhancing agricultural productivity and sustainability. Tadesses *et al*. (2021) revealed that interactions between agroforestry practices and altitudinal gradients, have a positive impact on the richness, diversity, and evenness of plant species, which corroborates efficiently with the present study. Researchers including Fetene *et al*. (2006) [4] and Rahbek (2005) [18] provide insights into the factors that contribute to this diversity, underscoring the importance of mid-altitude ecosystems in supporting both agricultural practices and natural biodiversity.

Research conducted in the Solan district of Himachal Pradesh has highlighted the diversity of agroforestry systems. Bhutia (2017) [2] reported that these systems contain between 13 to 18 components in the agri-horticulture system, varying along an elevation gradient. Similarly, Kapoor (2020) [8] observed a narrower range of functional units between 13 to 15 within the horti-agriculture system at altitudes between 2,400 and 2,700 meters in the wet temperate zone. Furthermore, studies by Matber (2014) [11], Rajput (2010) [19], and Sharma (2022) [21] have demonstrated variability in the number of functional components across different agroforestry systems. This highlights the complexity and diversity of agricultural practices present in this region.

Table 2: Functional components of Apple-based agroforestry system among farmer's categories in different altitudinal zones of Mandi district (H.P)

Hortipasture system				
Tree species			**Pasture**	
Age of fruit tree	**Density (per ha)**	**Average holding (ha)**	**Grasses**	**Net cropped area (ha)**
Altitudinal zone-I (1500-1800 m)				
Marginal				
Malus× domestica (~15yr)	216	0.75	*Cymbopogon martini, Aundinella nepalensis, Setaria glauca, Andropogon nardus*	0.25
Small				
Malus× domestica (~15yr)	233	0.75	*Aundinella nepalensis, Setaria glauca, Desmostachya binnata, Cymbopogon martini, Bothriochoa pertusa, Chrysopogon gryllus, Imperata cyclindrica*	0.25
Semi-Medium				
Malus× domestica (~15yr)	250	0.75	*Imperata cylindrical, Dactylis glomerata, Saccharum spontanum, Cynodon dactylon*	0.25
Altitudinal zone-II (1801-2100 m)				
Marginal				
Malus× domestica (~16yr)	216	0.75	*Chrysopogon gryllus, Apluda mutica, Setaria glauca, Chrysopogon montanus*	0.25
Small				
Malus× domestica (~18yr)	233	0.75	*Dactylis glomerata, Brachiaria mutica, Avena sativa, Andropogon nardus*	0.25
Semi-Medium				
Malus× domestica (~18yr)	250	0.75	*Dactylis glomerata, Brachiaria mutica, Avena sativa, Andropogon nardus, Dactylis glomerata Heteropogon contartus*	0.25
Altitudinal zone-III (2101-2400 m)				
Marginal				
Malus× domestica (~20yr)	233	0.75	*Dactylis glomerata, Chrysopogon gryllus, Chrysopogon montanus, Digitaria stricta, Dichanthium annulatum*	0.25
Small				
Malus× domestica (~20yr)	233	0.75	*Dichanthium annulatum, Chrysopogon montanus, Chrysopogon gryllus, Themeda anathera, Cynodon dactylon, Festuca arundinacea, Dactylis glomerata*	0.25
Semi-Medium				
Malus× domestica (~22yr)	250	0.75	*Desmostachya binnata, Dichanthium annulatum, Dactylis glomerata, Bothriochloa pertusa, Cynodon dactylon, Chrysopogon montanus, Bromus inermis*	0.25
Altitudinal zone-IV (2401-2700 m)				
Marginal				
Malus× domestica (~15yr)	200	0.75	*Dactylis glomerata, Chrysopogon montanus, Chrysopogon gryllus, Dichanthium annulatum,, Cynodon dactylon, Poa annua*	0.25
Small				
Malus× domestica (~16yr)	216	0.75	*Chrysopogon montanus, Chrysopogon gryllus, Dichanthium annulatum, Cynodon dactylon, Festuca arundinacea, Poa annua, Dactylis glomerata*	0.25
Semi-Medium				
Malus× domestica (~16yr)	233	0.75	*Digitaria stricta, Chrysopogon gryllus, Setaria glauca, Chrysopogon montanus, Poa annua*	0.25

Conclusion

In wet temperate areas, farmers have been practicing agroforestry by growing agricultural crops under apple trees. This practice has several benefits. Firstly, it optimizes land use by utilizing the space between apple trees for growing other crops, thereby increasing overall productivity per unit area. Secondly, it provides additional income streams for farmers as they can cultivate multiple crops simultaneously. Additionally, intercropping with agricultural crops under apple trees can help in soil conservation, moisture retention, and biodiversity enhancement. Overall, this approach showcases sustainable farming practices that contribute to both economic and environmental sustainability in the region.

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