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PROSPECTION OF MULTI-USE TREES FOR SUSTAINABLE MANAGEMENT OF MICRO-BASINS HIGH ANDES

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Abstract

The degradation of natural resources, rural poverty and loss of traditional knowledge characterize the Andean region and the Chimborazo River micro-basin. To face these problems, generate information and promote agroforestry as a priority alternative, this study was proposed as part of one of the research-development projects carried out by INIAP. Multiple use trees (MUT) were identified through the active participation of the inhabitants and prioritized the yagual (*Polylepis racemosa* H.B.K.), malva roja (*Lavatera assugentiflora* K.), tilo (*Sambucus nigra* L.), kishwar (*Budlleja incana* R&P.), lupino (*Genista monspessulana* L.A.S.), llin (*Senna multiglandulosa* J.H.S., *S.* sp.), kolle *(Buddleja coriaceae* H.B.K.), piquil (*Gynoxis* sp.), futag (*Salvia macrostachya* K.). Simultaneous agroforestry systems were identified, 47.14% are of the agrosilvicultural type, 28.27% silvopastoral and 14.29% agrisilvipastoril. Woody biomass, yield at the tree-crop interface, carbon fixed, and amount of firewood vary in each AS. Lupine, tilo, and malva are used as forage, which could become a viable alternative for animal feed. Forty-two seed sources were registered based on the characterization parameters generated with the Bioforesta Center, in addition, it consists of piquil (*Gynoxis* sp.), chachacón (*Escallonia myrtilloides* L.F.), árbol solitario (*Buddleja pichinchiensis* K.) and fagus (*Fagus americana*). In the nursery, the multiplication of yagual, lupino and tilo was systematized; and, in the laboratory, the quality of lupino, colle, chachacón, malva roja, lupino, mil, llin, piquil and kishwar seeds was determined. Nurseries and multiplication techniques are scarce and still need to be improved, hence the need to validate the MUT evaluation parameters and generate multiplication protocols. Additionally, the prioritized MUT could be consolidated for the management and integrated management of watersheds.

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INTRODUCTION

The tropical glaciers of Latin America are located mostly in the Andes Mountains: 71% in Peru, 22% in Bolivia, 3% in Colombia and 4% in Ecuador, and form 98% of tropical glaciers (Franco, 2008), its accelerated decline since the 70s is an indicator of the evolution of the climate (Schoolmeester et al., 2018), one effect of these changes refers to the hydrological regime of the basins (IPCC cited by Martínez 2004). Franco, (2008) stated that the deglaciation in recent years was 27.8 %. In Ecuador the snowy Chimborazo loses 0.5 m of ice year^{-1} Francou cited by Josephs (2007); Therefore, if this trend continues, the glaciers (located below 5500 masl) will disappear in 20 or 30 years (Bautista y Correa, 2018; Quintero, 2018).

In mountain basins, the Andean grassland is the ecosystem with the greatest coverage in the territory and contributes 80 % in water regulation (Cervantes et.al, 2021). Measuring the contribution of ecosystems in the generation of ecosystem services is not an easy task, mainly due to the extreme diversity and complexity of the Andean region (Ochoa-Tocachi et al., (2016), most of the water balance models give less weight to the vegetation and others do not even consider it (Bellot & Chirino, 2013; Touhami, 2014).

The use that man has given to the paramo dates 10,000 years ago, this renewable natural resource located above 2800 masl and with a coverage equivalent to 4.7% of the earth's surface (Hofstede and Mena 2000), constitutes territories suitable for breeding of animals, it provides sustenance to farmers and herders, it is a source and regulator of the hydrological system, and in the future, the possible source of hydroelectric energy (Yaguache et al. 2000).

In the Andean zone, the paramos and high mountain forests are in constant deterioration due to the indiscriminate felling of forest resource without proper replacement (Ramos et al., 2020), along with other factors such as forest fires, erosion, and overgrazing, can have severe consequences for the ecosystem, including soil degradation and loss of biodiversity (Nieto et al., 2004; Poca, et al 2018).

The micro-basin of the Chimborazo River located in the province of the same name, has an area of 12133 ha and an elevation range that goes from 3240 masl to 6280 masl. It constitutes about 60% of the San Juan parish (Riobamba-Ecuador canton) that extends from 3000 masl in the vicinity of the parish capital to 5000 masl on the slopes of the snowy Chimborazo; This parish has about 20000 ha of paramo and 5000 ha of Andean valley, where agricultural activity predominates, although this is not precisely its natural vocation (FAO 1995, Ramos 2006), which shows the importance of the area for the sustainable management of natural resources.

There is an urgent need to identify strategies for the preservation, restoration, and management of ecosystems (Beller et al., 2020). Population growth, the expansion of the agricultural, livestock and industrial frontier worldwide exert strong pressures on natural ecosystems (Allan, 2004; Sanches et al 2007). In this context, agroforestry is an important option when combining production, conservation, and provision of ecosystem services (Yaguache, 2004), especially in the mountains, as it is one of the regions with the greatest problems of degradation of natural resources and lack of competitiveness. agro-productive (Nieto et al., 2005).

For some time, researchers have tried to determine the influence of vegetation cover on soil and water conditions (Villegas, 2004 cited by Carrasco et al., 2023). In this study, we identified and characterized the multiple-use trees (MUT) in the Chimborazo river micro-watershed, through the participation of producers from the communities grouped in the San Juan Campesino Organization Union (UCASAJ) and the Federation of Organizations indigenous peasants from the slopes of Chimborazo (FOCIFCH) of Riobamba-Ecuador, which allows us to generate information on these ecosystems to develop programs for the protection, management and restoration of high Andean basins.

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Materials and Methods

Study area

The research was carried out in the Chimborazo River micro-basin, source of the Chibunga river sub-basin, a tributary of the Chambo river that adjoins the Pastaza River basin (PDA-UOCIC 2006; PNF, 2008). Geographically it is located to the northwest of the province of Chimborazo (Riobamba, San Juan), with an altitudinal ranged from 3240 to 6280 masl (PNF, 2008). 50% of the communities belonging to the union of intercommunal indigenous peasant organizations Chimborazo Rey de los Andes (UOCIC) are part of the Chimborazo faunal ecological reserve, they are communities that are above 3500 masl (Sanjapamba, Granquis, La Delicia, Tambohuasha, Shobol Llinllin, Chimborazo, Santa Isabel, Calera Grande (PDA-UOCIC 2006).

The distribution of rainfall is zenithal or equinoctial, with heterogeneous seasons, the area presents rainfall of up to 1100 mm year^{-1}, the relative humidity ranged from 75 to 80%. The average temperature is 10 ºC with daily variations, mainly in the months of November and December, which determines the presence of frost, a determining factor in the loss of crop production (PDA-UOCIC 2006; PNF, 2008; INAMHI-San Juan).

The soils are derived from volcanic ash, with undulating and broken topography, on the slopes of Chimborazo there is wind erosion, with the outcrop of a layer of pumice 1 to 2 cm thick (Cañadas, 1983), Great Criandepts group and those of the Mollisols order, suborder Udolls, Great Haploudolls group (Vallejo 1986).

The participating communities were Pulinguí San Pablo, Chorrera Mirador, Cooperativa Santa Teresita and San Luis de Chinigua from the FOCIFCH organization and La Delicia, Chimborazo, Santa Isabel, Santa Martha, Shobol Llin, Pisicaz, Calera Shobolpamba.

To facilitate the study and work in the field, three strata were formed (High stratum = between 3715 and 4000 masl, made up of the Pulinguí San Pablo, Casa Condor, Chorrera Mirador, Cooperativa Santa Teresita and San Luis de Chinigua communities; Medium stratum: included between 3501 and 3750 masl, made up of the communities: Tambohuasha, La Delicia, Chimborazo, Santa Isabel and the Santa Martha Association and Low stratum = between 3250 and 3500 masl, made up of the communities Shobol Llinllin, Cordillera de los Andes Association, Pisicaz and Shobolpamba Calera Association).

Experimental procedures

Secondary and primary information on multiple-use trees (MUT) was collected through field observations, informal conversations, and workshops with the participation of key informants. For the classification of ecosystem products and services of the MUT, secondary information was considered. The products were considered *i*) branches for brooms, *ii*) firewood for cooking and heating, *iii*) seed, *iv*) ropes for tools, *v*) fodder for larger animals, *vi*) for smaller animals, *vii*) parts of the plant for handicrafts, *viii*) handicrafts, *ix*) for tea and soft drinks, *x*) for shampoo, *xi*) fruits for food, *xii*) parts of the plant for natural insecticides, *xiii*) wood for stakes and *xiv*) long rods or posts for rustic constructions. The following benefits: *i*) shelter for animals-birds or kjarkas, *ii*) windbreak (huaira kjarkay), *iii*) prevention of erosion and soil protection, *iv*) crop protection (mainly frost reduction), *v*) recycling of nutrients, *vi*) moisture retention, *vii*) shade for animals, *viii*) agroforestry associations, scenic beauty, *ix*) medicine products for adults, *x*) for children, *xi*) unique products to cure older animals and *xii*) animals minors. The functional criterion (Ospina, 2006) was applied for the prioritization of MUT, and an ordering of frequencies of uses was carried out applying the triangulation of criteria.

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Systematic sweep-type tours were carried out in the communities to identify MUT in AS. The following was recorded: *i*) stem diameter (cm) at 30 cm from the ground, *ii*) height (m), *iii*) aerial biomass using the average tree technique (kg ha^{-1}) (MacDiken, cited by Andrade and Ibrahim 2002), *iv*) diameter of the crown (m), *v*) positive or negative interactions in an interface area of 2 m in the crop-woody subsystem, where it was considered: *a*) presence of pests and diseases, *b*) days to flowering, *c*) days to maturation, *d*) crop biomass, *e*) usable yield. The complementary variables and indicators were: *i)* fraction of Carbon (C) in the woody component (%). *ii*) amount of firewood collected (MT ha^{-1}). *iii*) nutritional value of forage MUT.

Each *identified seed source* (IF) was qualified by means of a table for selection based on the valuation of multi-use species generated with the support of the Bioforesta center. The IF and/or *conservation sources* were georeferenced. Community nurseries were visited and, in the nursery, the taking of yagual, tilo and lupino was evaluated and in the laboratory the protocols for the analysis of forest seeds (physical, physiological, and sanitary quality) were applied.

Results and discussion

Characteristics and uses of AUM

Native and naturalized MUT were found in association with other species on boundaries, home gardens, mini-woods, and in relicts next to water sources and streams. The technical handling of the woody component is minimal. In the upper stratum, adapted MUTs were identified above 3500 masl as: “yagual”, “kishwar”, “colle”, “piquil” and “tilo” (Jórgensen and León, 1999). In the National Herbarium, the introduced woody *Fagus americana* was classified. Few specimens of “arrayán” (*Eugenia rhopaloides* K.), “aliso” (*Alnus acuminata* K.), “guarango” (*Caesalpinia spinosa* Mol.O. Kuntz) and “capulí” (*Prunus serotina* E.), due to the range of distribution of the species.

The “colle” (*Buddleja coriacea* H.B.K) It is a slow-developing native tree (Añazco, 2000) and it is incorporated into the AS. with yagual and kishwar. In the middle stratum, it was found “chachacón” (*Escallonia myrtilloides* L.F.), preferred species because it has one or two stems and few branches. The “white kishwar” (*Aegiphilia ferruginea* H&S.) It would constitute an agroforestry option because it adapts up to 4,000 masl. The “árbol solitario” (*Buddleja pichinchiensis* K) (Caranqui, 2008) classified as a source of conservation.

The native tree “mil mil” (*Senna multiglandulosa* J.H.S.) is known locally as llin llin o chin chin, which generated confusion with the endemic “llin llin” or “mil mil” (*Senna* sp.); from now on they will be mentioned by the local name trying to respect the ancestral vision. The seeds of mil mil are rounded, shiny dark brown in color, homogeneous, and have finer and smaller glabrous leaflets, while the seeds of llin llin are flattened, light brown in color with a darker embryonic area and almost smooth leaflets (Caranqui, 2008). The “yagual” It is a native tree appreciated for its phenotype, the bark sheets are used for handicrafts and the agroecosystem services are recognized in the communities. *Polylepis racemosa* H.B.K. It is an introduced species from Peru (Caranqui, 2008) and it was found in agroforestry associations, while the endemic ones *P. reticulata, P. incana, P. sericea* (Jørgensen y León, 1999) They were found in mini-bosquetes, slopes and relicts next to the water springs. The "kishwar" (*Buddleja incana* R&P.) It is used in agroforestry, for firewood, wood for plowing implements, and medicinal practices. The “tilo” (*Sambucus nigra* L.) it is preferred for medicinal qualities; the producer carries out training pruning and uses the resulting vegetative material as seed.

Characteristics and uses of the shrubs

The “chilca” (*Baccharis latifolia* R&P., *B. Macracantha* R&P.) as one of the most prolific shrubs (Añazco, 2000). On a boundary close to the slope of the La Delicia community, from the lower

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stratum was found the “quismoso” (*Ageratina pseudochilca* B.) and the communities showed interest in propagating it. The extract of the fruits of “pishi” (*Monina* sp.), It is used as a dye for fabrics and to clean shoes. As for the “lupino” (*Genista monspessulana* L.) It is used as fuel, ornamental, forage for guinea pigs and rabbits, and as medicinal; it was found in windbreaks and live fences in the lower stratum. The "malvas" are found in home gardens, the flowers and leaves of the “malva blanca” (*Malva sylvestris* K.) are used in medicinal practices, the plant persists up to 4 years, while the “malva roja” o rosada (*Lavatera assugentiflora* K.) it is preferred because it persists up to 6 or 7 years according to local testimonies, which ensures the availability of forage although in reduced quantities due to the low density of plants in agroforestry associations.

The inhabitants use the "marco" as medicine and natural insecticide, it is one of the species that requires more management. Three species of “piquil”, two shrubs (*Gynoxis buxifolia* K.C y *G.* sp.) and a native tree (*G. hallii* H.) dispersed in mini-bosquetes or relics above 3600 masl in the micro-watershed, it is preferred for the quality of firewood and because the branches serve as a spinning tool. To the “futag” (*Salvia macrostachya* K.) It was found naturally, in the lower and middle zone, on borders and orchards, and it is used in traditional medicine.

Analysis of local knowledge about the MUT

The information from the workshops highlights the greater participation of the low-income communities with 80.71% of attendees. The greater participation of women (with a 4 percentage point difference with respect to male participation) is attributed to the same local demography, with the female population being higher than the male population with 9.12 percentage points (PNF, 2008). The woman is the one who has accumulated local knowledge through daily practices, since man, although he possesses valuable knowledge and also participates in agroforestry management, is the one who generally emigrates (Añazco, 2000). The average frequency of the products obtained (*niP*) was 14.05, a higher value than the average frequency of services (*niS*) of 13.33. The yagual, lupino, kishwar, chilca, tilo, llin llin, retama, futag, capulí, apuk, marco y malvas, were considered the priority local species to obtain important products for family life (Añazco, 2000). Regarding MUT services, the following stand out: the tilo, marco, chilca, futag, yagual, kishwar, malvas, llin, guantug, capulí, retama, lupino and pishi.

MUT prioritization analysis

The prioritization suggests MUT that can be used to propose agroforestry alternatives or selective reforestation. The triangulation allowed to weigh the MUT from different perspectives when considering the vegetative and distribution characteristics, the products and ecosystem benefits, the agroforestry potential, and the preferences of the inhabitants. The study indicates the interest of families based on the products and services provided by the MUT (Table 1) rather than their origin.

Table 1. MUT prioritized in the Chimborazo River micro-watershed. Riobamba, Ecuador.

No.	Local name	Scientific name	Uses (products or services)
1	Yagual o yaguil	*Polylepis racemose* H.B.K. *P. incana* K. *P. sericea* W.P. *P. lanuginose* K. *P. reticulata* H.	Firewood
2	Malva roja	*Lavatera assugentiflora* K.	Crop associations
3	Tilo	*Sambucus nigra* L.	Abcient medicine
4	Kishwar	*Buddleja incana* R&P.	Fodeer (food for animals)
5	Lupino o alfalon	*Genista monspessulona* L.A.S.	Food for people, scenic bauty and pollination
6	Llin llin	*Senna multiglandulos*a J.H.S.S.	Natural dyes
7	Juguerón	*Aegiphilia ferruginia* H y S.	Protection of watersheds and water

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			sources
8	Piquil	*Gynoxis halli* H.	Turism and recreation
9	Colle o yana kishwar	*Buddleja coriacea* H.B.K.	Wood for rustic constructions
10	Futak o churo morado	*Salvia macrostachya* K.	Tool stubs and brooms
11	Cilka	*Braccharis latifolia* R&P.P.	Stakes and implements for plowing
12	Guantuk	*Brugmansia arborea* L.	Seed source

Agronomic evaluation of MUT in Agroforestry Systems (AS)

AS identification: seven AS were identified. relevant in the lower stratum, each one results in a specificity (Table 2) and the products of the agricultural subsystem are mainly destined for family consumption due to cultural tradition. Most of AS were are privately owned and do not exceed 15 years of establishment, having received support for their implementation (57.14%) and others are the farmers' own initiative (42.86%).

The surface of the AS. it varies between 0.02 to 1.33 hectares, which makes it necessary to consider the tree-crop competition in the selection of species (Annaco, 2000). The ASs. The relevant ones are classified as simultaneous, of the agrisilvicultural type (57.14 %), followed by the silvopastoral (28.57 %) and agrisilvipastoral (14.29 %, Table 2).

Agroforestry technologies correspond to mixed orchards that constitute the smallest scale of agroforestry (Wood and Burley 1995) and are a traditional Andean system of land use managed mainly by women (Añazco, 2000). The most common agroforestry structure is made up of trees on boundaries with 85.71%, followed by windbreaks and trees in transitory crops with 71.43%; silvopastoral systems and orchards with 42.88%; the least common were the living fence and groves with 28.57 %, crops in strips with 14.29 % and no fallow practices were observed (Grijalva et al., 2010). Agroforestry alternatives are multipurpose from the functional and structural point of view.

Table 2. Types and technologies of AS relevant in the Chimborazo River micro-basin. Riobamba, Ecuador.

No.	AS simultaneous [1]		Farmer	Altitude	Coordinates MUT		Surface	Establishment	Qualif. [2]
	Type	Technology	Name/ community	masl	N	E	ha	Years/initiative	1- 5
1	Agroforestry	Woody in strips, terraces.	Silverio Ati Chimborazo	3 415	9 825 869	747 538	0.41	9/support	1
2	Agroforestry	Boundary and protection of ravine windbreak curtain.	Terreno comunitario Santa Isabel	3 360	9 825 676	745 233	0.90	15/ support	1
3	Agroforestry	Home garden, border.	Tobías Ati, Santa Martha	3 340	9 825 774	745 783	0.03	5/own	2
4	Agroforestry	Home garden, border.	Antonio Ati, Santa Martha	3 340	9 825 826	745 782	0.02	8/own	2
5	Silvopastoral	SSP border, Woody with grass.	Tobías Ati, Santa Martha	3 340	9 825 873	745 659	0.38	9/own	3
6	Silvopastoral	Woody with grass.	UCASAJ	3 340	9 825 447	746 715	0.70	7/ support	1
7	Agrosilvipastoril	Home garden, barrier with crops,pastures and/or trees.	María Lozano y José Gualancañay Shobolpamba	3 280	9 821 913	745 624	1.33	9/support	1

1 Type of AS. based on the classification of Añazco 2000b and Ospina 2006.
2 AS rating scale from 1 to 5: 1 excellent, 2 very good, 3 good, 4 fair, and 5 poor.

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Characteristics of the woody component

Table 3 shows the AS. outstanding, the density of the woody component and the relevant dendrological characteristics. in the ASs. the association of 2 to 7 woody plants is observed in the same agroforestry technology where the structure of multiple strata is reproduced with a high diversity of species and without a specific order. The most frequent MUT were yagual, kishwar, lupino, tilo and colle in various combinations, associations, and arrangements.

Table 3. Density and dendrological evaluation of the woody component in the selected AS of the Chimborazo River micro-basin.

No	AS[1]		Woody	Density	Qualif[2]	Height	Canopy	Thick branches	
	Name	No	Scientific name	%	1 exc, 5 worse	Calculated (m)	Diameter (m)	#	x Diameter (cm)
1	Chimborazo	1	*Ambrosia arborescens* Mill.	1.45	4	2.28	3.00	6	2.86
		2	*Salvia macrostachya* Kunth.	1.45	3	4.44	3.25	4	2.15
		3	*Prunus serotina* Ehrh.	2.90	3	4.55	4.30	1	22.76
		4	*Genista monspessulana* L.	10.14	4	3.70	3.37	2	7.58
		5	*Buddleja incana* Ruiz&Pav.	14.49	3	5.04	3.40	2	11.92
		6	*Sambucus nigra L.*	24.64	4	5.27	4.33	4	11.24
		7	*Polylepis racemosa* H.B.K.	44.93	2	4.77	3.33	3	11.26
2	Santa Isabel	1	*Eucaliptus globulus*	29.17	3	21.11	5.69	1	29.56
		2	*Buddleja incana* Ruiz&Pav.	70.83	3	6.16	6.44	5	19.22
3	Asociación Santa Martha Huerto integral “Los Lupinos”	1	*Buddleja incana* Ruiz&Pav.	2.45	3	4.28	2.83	2	8.90
		2	*Polylepis racemosa* H.B.K.	3.45	3	4.70	2.06	5	5.38
		3	*Sambucus nigra L.*	31.03	3	5.05	3.40	3	9.20
		4	*Genista monspessulana* L.	62.07	3	3.78	2.25	1	7.40
4	Asociación Santa Martha Huerto integral “Los Tilos”	1	*Polylepis racemosa* H.B.K.	1.05	3	3.89	2.30	3	6.05
		2	*Lavatera assugentiflora* Kellog.	2.10	3	2.90	1.95	1	6.37
		3	*Lavatera* sp.	3.16	2	3.57	1.87	1	8.36
		4	*Genista monspessulana* L.	33.68	3	3.06	1.69	2	5.92
		5	*Sambucus nigra* L.*	60.00	3	3.56	1.46	2	5.68
5	Asociación Santa Martha	1	*Buddeja coriaceae* H.B.K.	2.63	5	5.09	1.40	1	9.99
		2	*Buddleja incana* Ruiz&Pav.	97.37	3	4.38	2.92	2	12.82
6	UCASAJ	1	*Escallonia myrtilloides L.f.*	5.63	1	4.03	4.05	3	13.18
		2	*Buddeja coriaceae* H.B.K.	28.17	2	3.62	3.68	2	11.46
		3	*Polylepis racemosa* H.B.K.	30.99	1	4.46	3.33	4	11.44
		4	*Buddleja incana* Ruiz&Pav.	35.21	2	2.83	2.89	3	8.76
7	Asociación Calera Shobolpamba	1	*Polylepis racemosa*	1.96	3	2.17	3.39	2	14.82
		2	*Spartium junceaum* L.	1.96	2	1.78	4.53	4	9.81
		3	*Genista monspessulana* L.	33.33	1	1.79	1.27	2	2.69
		4	*Buddleja incana* Ruiz&Pav.	67.74	3	2.86	4.11	4	14.67

[1]In the ASs. 30 % of the woody plants were evaluated both for those in discontinuous rows and for the AS. more homogeneous like that of the UCASAJ; in AS 4, 70% of the lime was evaluated.
2 MUT rating scale from 1 to 5: 1 excellent, 2 very good, 3 good, 4 fair and 5 poor.

In the Table 4, are shown of biomass of the woody component, the shape or growth habit of the MUT prioritized in AS. is equal to or greater than 0.8, which indicates that the species are of the tree growth type (Jara, 1998) and determines the suitability of the species for local agroforestry alternatives. in the SA relevant to the micro-watershed, the aerial biomass of the yagual, lupine, linden, kishwar and colle was estimated, which correspond to different arrangements in agrisilvicultural systems: home gardens (AS 1, 3, 4), two silvopastoral systems (AS 5 and 6) and an agrisilvipastoral (AS 7).

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The 11-year-old lime tree accused the highest amount of aerial biomass with 74670.60 kg ha^{-1} in AS 4; in the same AS, the lupine accused 31.23 % less biomass than in the AS 3 due to the age difference of the woody ones, thus the lupino in the AS 4 of 3 years of establishment and in the AS 3 of 6 years. In AS 1 the yagual reported 12102.60 kg ha^{-1}, while in the UCASAJ silvopastoral system, González (2009) reports higher values (16269.37 kg ha^{-1}), which also occurs with the colle (in AS 6 with 3013.33 kg ha^{-1} less than 11876.64 kg ha^{-1}). In systems 5 and 7, similar values were obtained for kishwar (9262.98 and 8751.48 kg ha^{-1}), comparable to the report by the same author (9436.23 kg ha^{-1}). It can be deduced that these differences are directly related to the density of woody plants based on the design of the AS, age, and management in each system (Table 4).

Table 4. Aerial biomass of the MUTs evaluated in relevant ASs of the Chimborazo River micro-basin. Riobamba, Ecuador.

No. AS	Woody							Biomass [2]	Fraction of C	C fixed	Firewood [3]
	Local nomber	Thick branches			Habit[1]	Diameter of the cup (m)	No./SAF	kg ha^{-1}	%	t ha^{-1}	t ha^{-1}
		h (m)	d (cm)	No.							
1	yagual	8.19	4.55	2	1.0	3.33	103	12 102.60	55.52	6.72	11.12
3	lupino	3.60	3.68	2	1.0	1.69	120	62 120.00	56.80	35.28	44.72
4	lupino	3.47	9.54	4	0.9	2.25	60	42 720.00	55.98	23.91	35.58
4	tilo	4.02	4.08	3	0.8	1.46	81	74 670.00	55.61	41.52	67.06
5	kishwar	3.21	3.79	5	0.8	2.92	123	9 262.98	54.77	5.07	7.60
6	colle	3.83	4.35	4	0.9	3.68	67	3 013.33	56.71	1.71	2.62
7	kishwar	5.53	5.67	2	0.9	4.11	213	8 751.48	55.74	4.88	7.58

[1]Proportion between the height and the length of the longest branch (Jara, 1998).
[2]Values expressed on a dry basis.
[3]Calculation for firewood based on the biomass of thick and thin branches based on local use. **Notation:** h height, d diameter.

Description of agroforestry systems

In the Santa Isabel community agroforestry system, integrated management is applied, and the potato crop (Solanum tuberosum L. var. Superchola) was evaluated in interaction with eucalyptus and kishwar. The biomass and yield of the crop was only 50.66 % higher than in the interaction with eucalyptus and 54.29 % higher than with kishwar, which can be attributed to the fact that morning and evening shading conditions by woody plants can retard physiological processes. in cultivation. The tuber biomass was 50.47 % with eucalyptus and 48 % with kishwar, lower than the crop alone, which is attributed to the poor management of woody plants. Interference in the interface area is positive because *Phytophthora infestans* It presented less severity than in the culture alone, which could be related to the generation of unfavorable environmental factors for the dissemination of zoospores .

Agroforestry system “Los Lupinos” there is a high density and diversity of plants and natural and ecological management is practiced. Aerial biomass and cabbage yield (*Brassica oleraceae* L.) and the cauliflower (*Brassica oleraceae* L. var. Botrytis) in the interphase with lupino and tilo it was higher compared to the crop alone because the woody plants maintain an appropriate microclimate for the development of vegetables. The negative influence is detected in the case of chard (*Beta vulgaris* L. var. cicla) and grass (*Lolium perenne*); however, the aerial biomass of the vegetable-lupino subsystem would be higher than the aerial biomass of the vegetable subsystem.

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Silvopastoral system (SSP) "Santa Martha" It constitutes a naturalized pasture where controlled grazing is practiced by rope and occasionally cutting, the average botanical composition of the interface revealed 46 % of perennial ryegrass (*Lolium perenne*), followed by clover (*Trifolium repens* L.), blue grass (*Dactylis glomerata* L.), alfalfa (*Medicago sativa* L.) and cebadilla (*Bromus catharticus*); and for pasture, 40% of ryegrass, trébol blanco, cebadilla y pasto azul. In the interface area with kishwar, a biomass and yield higher than that obtained in the open field was obtained, due to the location of the windbreak curtain and at the same time boundary, it does not generate morning shade, on the contrary, the pasture benefits from the organic matter produced by the litter of the kishwar trees and the microclimate they generate.

Agroforestry system "Los Tilos" the density of the woody component is high and in the herbaceous component it is low, there is a high diversity and natural and ecological management is practiced. Aerial biomass and yield of purple cabbage (*Brassica oleraceae* var. red rock M.), grass (*Lolium* perenne) and cauliflower (*Brassica oleraceae* L. var. botrytis) at the interface with tilo and lupino it was lower compared to the culture alone. The management of woody plants is evidenced by training pruning. However, a key factor is the shadow generated around the arable area due to the north, south and west orientation of the woody component and an infrastructure located to the east. Additionally, the owners of the AS do not perform root pruning, they only avoid cultivating near the trees (interface area) because they assume the competition of the woody-crop root system.

The SSP UCASAJ established in 2001 with objectives of agroforestry research/demonstration, is made up of kishwar, yagual, colle dispersed in a 0.7 ha plot with a density of 400 trees/ha and a naturalized pasture where controlled grazing is practiced. Despite the numerical differences, there does not seem to be an effect on the amount of dry matter, aerial biomass, and pasture yield, in the interface area. The results respond to the evaluation of biomass in an interface area of 2 m with the management granted by the small producer. In this SSP, in the rainy season, with systematic cuts and considering an interface area of 3 m, González (2009) obtained the highest amount of pasture biomass in the colle subsystem (2 513.12 kg), followed by yagual (2 468.85 kg) and kishwar (2 215.77 kg) and for the natural grassland the least amount (958.94 kg); which is attributed to the composition and management of the SSP with respect to the natural meadow (Grijalva et al. 2004). Other studies have shown that the use of trees in pastures allows obtaining greater amounts of biomass compared to monoculture pastures.

Agrosilvipastoral system "Calera Shobolpamba" there is a low density of plants and natural and ecological management is practiced. Aerial biomass and yield in interaction with lupino of green cabbage (*Brassica oleraceae* L.) was superior to that of purple cabbage (*Brassica oleraceae* var. red rock M.) and chard (*Beta vulgaris* L. var. cicla) doubled these values. No interaction was distinguished since the vegetables were outside the interface area with lupino and there was a negative interaction in the production of aboveground biomass and the yield of the degraded naturalized pasture with kishwar in the interface area.

Fraction of C the woody component

The average value for the MUT was 55.79 %, the fraction of C in thick branches (57.07 %) was higher than that of thin branches (56.62 %), leaves (54.37 %) and flowers (52.20 %) due to structural differences (Table 3). For their part, other authors consider the fraction of carbon in dry matter to be 50 % for all species. The C fixed per hectare in the woody component is directly related to the establishment time of the woody plant, the density and management of the component by the small farmer. so, the system "Los Tilos" fixed the highest amount of C per hectare, followed by lupino, yagual, kishwar and colle; which is added to the studies that demonstrate that the AS, they can reduce atmospheric C emissions by the assimilation of CO_2 in tree biomass and agroforestry activities can be implemented to mitigate global warming (IPCC, 2001).

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Amount of firewood collected

The families of the micro-watershed prefer chilca firewood, followed by the species that were prioritized in the AS: yagual, kishwar, lupino, tilo and colle. The firewood collected in the AS, it is directly related to the dendrological characteristics of the woody and biomass; the largest amount of firewood contributes the tilo tree in the AS "Los Tilos" and the lupino in the AS "Los Lupinos" (Table 3), values that differ from González (2009) for kishwar, colle and yagual in the AS "UCASAJ", considering that they are annual reports, unlike the accumulated values obtained in this investigation, in this sense the agroforestry associations could reduce the pressure on the remnants of MUT.

Nutritive value of trees with fodder aptitude

The rural population of the micro-basin uses the lupino, tilo, and occasionally the malva, as forage for guinea pigs, sheep, and cattle, which according to other research can improve productivity and provide an economically viable alternative for animal feed. The nutritional value of tender leaves of malva y medium ripe lupino and tilo reported high protein and energy values, which defines an ideal state for cutting and derives an indirect relationship between the percentage of protein, digestibility, intake, and forage age (Table 5). The tilo presented the highest percentage of crude protein, followed by malva, alfalfa, lupino and the degraded naturalized pasture, which shows that the MUT of the AS they can be used as forage, considering that cattle in times of grass scarcity depend on tree and shrub forage (Nieto et al. 2004).

Table 5. Chemical composition of multiple-use trees in AS of the Chimborazo River micro-basin. Riobamba, Chimborazo.

Forage	Dry material	Protein	Fiber	Calcium	Phosphorus	Metabolizable energy
Common name	%	%	%	%	%	Mcal/kg
Lupino	27.42	18.63	23.80	0.79	0.22	2.71
Malva	22.28	28.72	17.53	2.24	0.42	2.41
Tilo	14.63	33.49	16.44	0.85	0.47	2.37
Alfalfa	21.90	22.20	24.00	-	-	2.67
Degraded naturalized pasture	31.00	11.20	24.5	0.52	0.18	2.05

Notation: Chemical composition of alfalfa cited by Grijalva (2009), degraded naturalized pasture cited by González (2009).
Source: INIAP-EESC Department of nutrition and quality. Food analysis and research service laboratory. Values expressed on a dry basis**.**

Identified seed sources (ISS)

42 ISS and occasionally *conservation sources* were recorded based on the parameters generated for the characterization of ISS (Narváez 2004*) **of*** kishwar (*Buddleja incana* R&P.), yaguales (*Polylepis racemosa* H.B.K, *P. incana* Kunth., *P. sericia* Weed. *y P. reticulata* Hieron), futag (*Salvia macrostachya* Kunth), haya (*Fagus* sp.), piquil (*Gynoxis* sp.), colle (*Buddleja coriacea* H.B.K), chachacón (*Escallonia myrtilloides*) y árbol solitario (*Buddleja pichinchensis* Kunth H.B.K.).

Systematization of MUT multiplication techniques

Two private nurseries were identified in the micro-watershed: "Vivero plantas" and "San Juan" and a community nursery "UCASAJ" where they exchange experiences with nurseries "San Francisco de Cunuguachay" and "Alao LLactapamba", located outside the study area. The most common MUT in

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nurseries in the area are: kishwar, llin, yagual and lupino, Furthermore, according to reports, they are the most demanded species in the province of Chimborazo.

Asexual reproduction techniques

The nurserymen collect the vegetative material from the "female" trees of yagual or those that contain preformed cuttings, to ensure 60% take. In the nursery, the taking of yagual was regular with 3.8 points, which is attributed to the lack of experience in the collection and handling of cuttings and/or to the scarce ISS availability in the area. In the asexual propagation of the tilo tree, the vegetative material from the prunings is used to extract the greatest number of seeds, leaving a maximum of two leaves per stake, with this procedure an excellent take was obtained.

Techniques of sexual reproduction

The population harvests the lupino when the pods open on their own, they are then dried in the shade for 15 days (which should be a maximum of four with respect to secondary information). They sow the seed in a continuous stream in beds, and when the seedlings have 3 true leaves, they are planted in plastic bags. In the nursery, the lupine apprehension qualified as very good with 2.17 points out of 5 (scale).

Seed analysis

The percentage of purity is related to the characteristics of each fruit and the post-harvest treatment. The moisture content in the seeds was 9.2 to 13.2 %, which places them in the range (6 to 10 %) verified for orthodox species. The number of seeds per kilogram for kishwar coincides with studies by several authors, as well as the lupino, piquil and colle they are related to the data from Bioforesta (2009); for chachacón, mil and malva roja there is no information available, however, a direct relationship is established between the size and weight of the seeds, with the percentage of germination (Table 6).

In the nursery, the average germination percentage was 8.4 %, being the highest for chachacón (40 %) and with a negative answer in the case of piquil. In the laboratory, an average germination percentage of 21 % was obtained and in the best of cases it does not exceed 53 %. Several authors affirm that most of the high Andean Forest seeds germinate without much difficulty, however the results obtained can be attributed to internal and external factors of the seed and others related to management, which allows suggesting readjustments in the nursery for seed reproduction. Lowest percentage of fungal contamination (*Aspergillus sp.*) of the seeds went to the piquil and the greatest for llin, lupino and mil; For this reason, it is necessary to standardize seed quality determination tests and generate MUT sexual multiplication protocols in the laboratory and field, given the high demand for seeds in the micro-watershed and the Andean region.

Table 6. Analysis of multiple-use tree seeds in the UCASAJ nursery and in the Bioforesta-ESPOCH Laboratory. Riobamba, Chimborazo.

QUALITY					**PHYSICAL**			**PHYSIOLOGICAL**				**SANITARY**
Provenance			**Seed purity**			**Humidity**	**Number seeds /kg**	**Nursery UCASAJ**		**BIOFORESTA Center**		
Altitude	Community	Especie	Pure	Cont.	Inert matter	16-17 h		GI	G	GI	G	Cont..
(m)	Nomber	Local nomber	%	%	%	%		No	%	No	%	%
3 280	Pisicaz	*Genista monspessulana*	92.1	7.00	0.90	10.50	148 148	9	7	8	35	10
3 330	UCASAJ	*Buddleja coriácea*	8.1	91.90	0.00	9.20	1 851 852	11	23	6	53	15

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3 350	Santa Martha	*Escallonia myrtillioides*	57.0	0.00	43.00	12.50	88 500 000	8	40	14	5	0
		Lavatera assugentiflora	41.1	2.70	56.20	14.00	33 256	4	4	14	24	0
		Genista monspessulana	69.2	30.80	0.00	10.10	163 399	-	-	6	15	70
3 470	Chimborazo	*Senna multiglandulosa*	42.5	9.70	47.80	9.20	26 940	4	12	6	7	70
		Senna sp.	80.0	17.80	2.20	13.20	12 145		8	23		100
3 560	Incas	*Gynoxis* sp.	48.3	22.00	29.70	13.20	1 851 852	0	0	25	0	2
3 280	Shobolpamba	*Buddleja incana*	88.0	0.00	12.00	6.80	5 300 000	-	-	-	-	-

Notation: days to initial germination (GI), germination (G), contamination (Cont.).

Conclusions

The communities of the Chimborazo river micro-watershed obtain products and services from multiple use trees (MUT), the most functional were yagual (*Polylepis racemosa* H.B.K., *P. incana* K.), malva roja (*Lavatera assugentiflora* K.), tilo (*Sambucus nigra* L.), kishwar (*Budlleja incana* R.&P.), lupino (*Genista monspessulana* L.A.S.), llin (*Senna multiglandulosa* J.H.S. y *S.* sp.), colle *(Buddleja coriaceae* H.B.K.), piquil (*Gynoxis* sp.), futag (*Salvia macrostachya* K.) and, chilca (*Baccharis latifolia* R.&P.P.).

Despite the diversity expressed in the number of MUT identified, the density in agroforestry systems (AS) or agroforestry initiatives are scarce. The ASs are made up of yagual, kishwar, lupino, tilo and colle, in simultaneous systems, which could be consolidated for the management and integrated management of hydrographic basins.

Identified and conservation seed sources were found, important to strengthen the plans related to the use of clean technologies in the micro-basin.

MUT nurseries and multiplication techniques are scarce and still need to be improved. The average take was good and regular, which reveals the need to improve asexual reproduction techniques to yagual and tilo and sexual in: malvas, kishwar, lupino, llin, mil, chachacón, piquil and colle, to ensure conservation and agroforestry massification.

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COMPETING INTERESTS

The authors have no competing interests to declare.

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