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Research Article

Conversion of an old, abandoned chestnut forest into simple coppice and coppice forest into orchards through the wise using of the agroforestry practices and estimated energy potential

Admir Seci[1], Sunitha N. Seenappa[2], Bashkim Mal Lushaj[3], Arnisa B. Lushaj[4], Arvjen B. Lushaj[5], Klodian Sina[5], Endrit Dega[5], Ilir Myteberi[6], Elvin Toromani[6], Vath Tabaku[6], Vasillaq Mine[6], Adesa Boja[7], Jonila Brahimi[8], and Blerant Sherif Lushaj[9]

[1]Ministry of Environment, Forests and Water Administration, "Durres" Street, No. 27, Tirana, Albania

[2]ECO-BELT R and D Pvt. Ltd., Managanahalli, Hosur Post, Ramanagara Tq and Dist., Karnataka, India

[3]Institute of Geosciences & Energy, Water & Environment, P.O. Box 244/1, "Don Bosko" Street, No. 60, Tirana, Albania

[4]L'école Nationale Supérieure d'Architecture de Paris La Villette (ENSAPLV), Paris, France

[5]Faculty of Civil Engineering, Polytechnic University of Tirana, Albania

[6]Faculty of Forest Sciences, Agricultural University, Koder-Kamëz, Tirana, Albania

[7]Eko Studio Projekt**,** Ltd., Tirana, Albania

[8]Faculty of Economics, University of Tirana, Tirana, Albania

[9]Forest Service of Tropoja district, Tropoja, Albania

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Abstract: The chestnut massive of Tropoja district is one among the biggest massifs in the Balkan region with a total surface of 2408.5 ha. It covers the city of Bajram Curri that is located between the Alps of Albania. Unmanaged chestnut (*Castanea sativa* Mill) forests that exposed to

diseases, infestations, and abiotic stress since 1960 to 1980 were considered for the sustainability in Tropoja District of North Albania, Europe. During the year 1981 permanent plots of 2.1ha of 10 numbers were established in two regions of Gashi and Krasniqe. Forest conditions (existing) recorded-number of chestnut trees, number of chestnut sprouts/saplings, observable diseases and infestations like blight disease (causal agent *Cryphonectria parasitica*), ink disease (causal agent *Phytophthora cinnamomi*) and yellow mistletoe. Of the ten plots, five plots were taken as control for the studies as coppice stands after removal of old and abandoned chestnut trees (of 90%) at an av. of 142-143 trees/ha, in the year 1982 at av. of 110 trees/ha and up till 2002 at av. 17-18 trees/ha were allowed for simple coppices then transformed into orchards from 2003 to 2008. Thus, maintained plots were ready for harvest in the beginning of the year 2013. The project has shown increased quality of timbers apart from eight-fold increase in growth and yield. As per the records in the year 1982 av. 4025 sprouts/ha were allowed. Simple coppice maintenance with relative rotation time of every five years, at 1983, 1988, 1993 and 1998 were done to record and observe the improvement of health of trees, by grafting and stimulation of crowns. As wise agrosilvicultural practices, thinning at every five years removed about 50% sprouts/ha by razor cutting for the benefits of fruit yielding. Reduced number of sprouts accounted av. 4025 to av. 1005 and further reduced to av. 225 trees/ha. The principal aim to convert simple coppice into orchards by removal of young trees that were unimportant in terms of fruit yield and timber growth. The chestnut trees were harvested during the beginning of year 2013 and the estimated trees/ha is av. 255 to av. 127-128 trees/ha, through the wise agroforestry practices. Planting of new orchards were carried out cover 50 ha higher than in the year 1981. At the same time was necessary to estimate the energy potential from biomass residues from chestnut and other cultures, and animal wastes, and to increase farm income.

Keywords: Agroforestry, chestnut orchards, fruit yield, agrosilvicultural practices, timber production, biomass energy.

INTRODUCTION

Forest bounty has been enjoyed since human civilizations across the globe and silvicuture practices are man-made activities for sustainability of the economically important trees mainly for timber and edible parts (like fruits and nuts/seeds). Continual exploitation without many drastic effects on the forest ecology for the economic viability of rural communities and stakeholders are possible by means of silviculture orientation[1]. A southern region of Europe is blessed with sweet chestnut (*Castanea sativa* Mill) forests in their habitats[2,3.] Their economic importance has gained surplus returns as timber uplifts socio-economic among rural populations[4,5].

In Albania, Tropoja district has been seen with chestnut forests since time immemorial. Improvement of forests from not only timber and fruit yield but in terms of forest stability, silivicultural aspects and implementations were the decisions. Involvement of two sectors as:

(1) Research needs expressed by the agriculture, forestry and wood sector and

(2) Research needs expressed by the scientific community.

As shown by the IEFC[6] and the excerptions are shown in the **Table - 1** which has been the similar needs proven in the Tropoja region (district) of Northern Albania**.** Their goals were to develop broad social and environmental stakeholder understanding for the agrosilvicultural practices of chestnut tree stands on sustainable grounds. The issues of the work group were addressing the key questions on stakeholders, avoidance of forest health threats by the work group to develop and execute plans to solicit broad input and engage key holders[6].

As per the works of Lushaj and Dini[3], in Tropoja district of Northern Albania, the chestnut trees cover an area of 2,408.5 ha. The traditional and conventional methods of timber harvest rotation took place once in 12-25 years. Since 1960's the care for trees minimized/almost abandoned due to labour-intensity and the negligence of the ruling governments leading to ecological population struggle[3] among chestnut trees, young trees and sprouts hampered the systematic growth and timber size[5] mainly attributable to diseases and infestations[7-9]. Much to the chagrin, later years (prior to 1980's) experienced illegal cuttings further dwindled the ecosystem balance and transformed high profiled agro-forestry into coppices[1,10].

Table-1: Agrosilvicultural decisions and involvement aspects in two different sectors and the conclusion drawn

Research needs expressed by the agroforestry and wood sectors	**Research needs expressed by scientific community**	**Conclusions drawn at the end of workshop**
Agrosilviculture forest planting and inventories: a) Risk management Forest health; Forest fires. b) Degraded forest rehabilitation. c) Biodiversity protection. d) Competiveness of the wood chains: Wood quality and products; Afroforest operations and equipments; Industrial processes by: Tree breeding, Socio-economics, Sustainable agroforest management; e) The estimated energy potential from biomass residues from chestnut and other cultures, and animal wastes; f) The planning of planting of the new orchards; g) Construction of watchtowers, and h) The estimated farm income.	Agrosilviculture and modelling by: Tree breeding, Forest health.	1 Agroforestry – wood section expressed their willingness to adapt their developmental strategies based on research for new market and society needs from the forests. 2 New agtosilvicultural implementation as and when the need arises demands; 3 Role of continual research based activity proposed. 4 Agroforest information systems emerged during the discussions. 5 Knowledge and technology transfer models for the benefits of the agrosilviculturists and wood sectors where known. 6 Knowledge and technology transfer models for the energy from biomass ect. 7 Knowledge and technology transfer models for the planting of the new orchards; 8 Knowledge for the construction of watchtowers; and 9 Knowledge for the increasing of the farm income ect.

(Source: References No. 3, 13, 17, 18, 20, 22, 28-32)

Recognition of social welfare in the agrosilviculture practices of chestnut trees: Interactive Forestry Health is the current trend practiced through agrosilivicultural practices for the upliftment of socio-economic status at one angle and for timber and fruit yield of chestnut trees on the other hand. Goals of the working group were to be developed. Rural populations of European Regions' survived on the traditional coppicing (short duration of 12-25 years) cultivation practices of chestnut in the past for fruit yield and timbers[5]. The forests were abandoned since 1960s were needed a new development under silivicultural practices[11]. The practices developed from the earlier basic knowledge based[5]. Besides side-by-side, research establishments are also required for the continual viability of the agrosilivicultural

practice[6] and our experiences[3]. Task B1. Regional workshop "Research needs for the sustainable management of cultivated forests" Consultation of the Portuguese forestry-wood chains actors. Project IMACORD – 5th Framework Programme Accompanying Measure.

Based on the workshop conducted by IMACFORD[6] and our experiences[3], it is clear that the (**Table: 2**) research needs expressed by the forestry and wood sectors and the research needs expressed by the scientific community in unidirectional ways concluding that:

1. Forest wood cutters expressed willingness to adapt their development strategies for new market and society needs;
2. New agrosilvicultural implementations;
3. Role of continual research accepted; and
4. Agroforest information systems engaged for the workshop discussions.

Table-2: Outlines of the workshop proving the requirement of research in agroforestry sustainability.

Research needs expressed by the agroforestry and wood sectors	**Research needs expressed by scientific community**	**Conclusions drawn**
Agrosilviculture forest planting and inventories: (a) Risk management Forest health: Forest fires. (b) Degraded soil rehabilitation. (c) Biodiversity protection. (d) Competiveness of the wood chains: Wood quality and products; Agroforest operations and equipments; Industrial processes by: Tree breeding, Socio-economics, Sustainable agroforest management; and (e) The estimated energy potential from biomass residues from chestnut and other cultures, and animal wastes. f) The planning of planting of the new orchards; g) Construction of watchtowers, and h) The estimated farm income.	Agrosilviculture and modelling by: Tree breeding, Forest health.	1 Forest wood cutten expressed their willingness to adapt their developmental strategies based on research for new market and society needs from the forests. 2 New agrosilvicultural implementation. 3 Role of continual research accepted. 4 Agroforest information systems emerged during the discussions. 5 Knowledge and technology transfer models for the benefits of the agrosilviculturists and wood sectors where known. 6 Knowledge and technology transfer models for energy from biomass 7 Knowledge and technology transfer models for the planting of the new orchards; 8 Knowledge for the construction of watchtowers; and 9 Knowledge for the increasing of the farm income ect.

(Source: References No. 3, 13, 17, 18, 20, 22, 28-32)

Objectives of the study: The importance of sustainable development to ensure "externalities" in terms of ecosystem and social welfare recognitions[10-12] were considered to emphasise agrosilvicultural practices for known and estimated profits[13,14] with semi-scientific knowledge-based activities under scrutiny in

Tropoja district, based on the earlier works and experiences to prove authenticity[18] that were followed since 1981 to this day.

Apart from analysing the *status quo*, the team took up wise and systematic management strategies not only to conserve chestnut forest biodiversity but uplifted the socio-economic status of the rural communities in a systematic manner for continual productions of fruits and timber[3,15.] The on-going project with its final stage was shown in the beginning of the year 2013 is been important criteria in the additions of GDP[16].

The current paper discusses the considerations and suitability of stand characteristics as basic indicators for the productivity in terms of harvests of timber and fruits in given the experimental and study locations (of several hectares of land area) for workable rehabilitation techniques to show and prove state-of-the-art simple practices pertainable to Tropoja District, for allowances of perfect valorization of timber quality with stipulated protocol/s.

MATERIALS AND METHODS

The following systems were adapted for the study and that could be developed as protocol for agrosilvicultural practices for chestnut trees under forest areas for sustainable productivity in Tropoja District, Northeast Albania, and Europe**. Fig. 1** shows map of Albania and district locations of study sites. **Fig. 2** shows managed chestnut coppice prior to orchard (Plot-3). **Fig. 3** shows the chestnut delimitation zone in Tropoja, plane and inclined view.

Study sties: Two study sites were selected as control (U) and as managed (M) in the regions of Gashi and Krasniqe of Tropoja District, Northern Albania. The study sites from Gashi region was Kerrnaje-Hoxhaj and from Krasniqe region were Margegaj-Shoshan, Markaj-Rosuje, Gri-Velisht and Selimaj-Lekurtaj. Both control and management study site area were taken as 2.1ha and study records taken from 1981 to 2013. As initial data climate history, distribution of chestnut trees and age of the trees were recorded **(Table 3).**

Fig. 1: Map of Albania showing district (location) of study sites

Fig. 2: Managed chestnut coppice prior to orchard (Plot – 3)

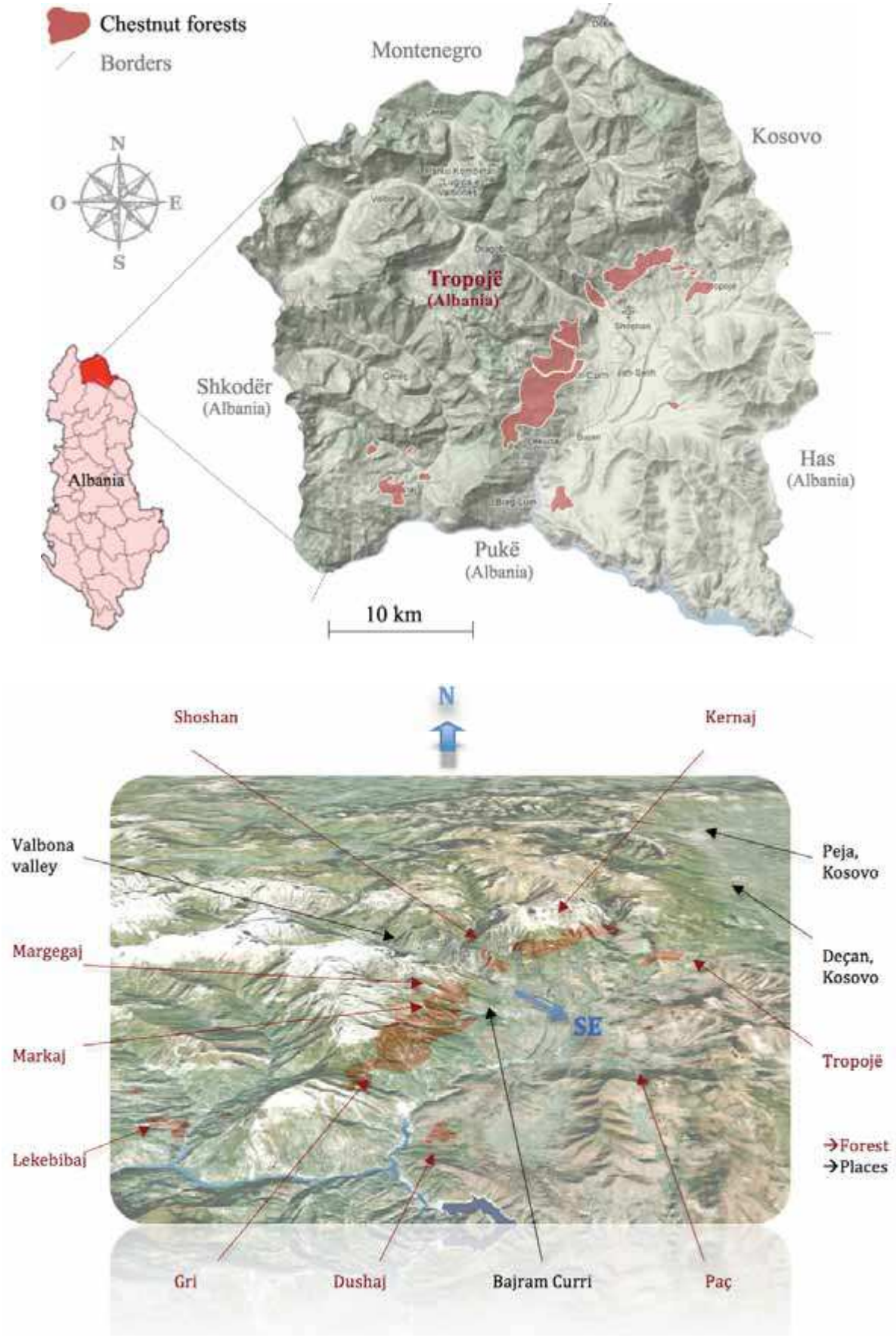

Fig. 3 Chestnut delimitation zone in Tropoja, plane and inclined view (Source: References Lushaj et al. 1999[18])

Table 3: Details of the study (1981 to 2013) and activity undertaken in two regions of Gashi and Krasniqe, in Tropoja District of Northern Albania

District	Tropoja									
Region	Gashi		Krasniqe							
Study site	Kerrnaje-Hoxhaj	Kerrnaje-Hoxhaj	Margegaj-Shoshan	Margegaj-Shoshan	Markaj-Rosuje	Markaj-Rosuje	Gri-Velisht	Gri-Velisht	Selimaj–Lekurtaj	Selimaj–Lekurtaj
Siviculatural treatment	*M	**U	M	U	M	U	M	U	M	U
Sip. (ha)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
No. trees on 1981	150	152	161	162	163	162	170	168	165	164
No. trees on 1982	15	152	16	162	16	162	17	168	16	164
No. of sprouts/tress on 1983	7998	154	8402	165	8505	170	8921	170	8661	166
No. of sprouts/tress on 1988	3999	156	4201	166	4250	170	4461	172	4331	168
No. of sprouts/tress on 1993	2000	149	2100	159	2125	160	2230	170	2160	165
No. of sprouts/tress on 1998	1009	145	1051	150	1067	150	1115	165	1081	165
No. of sprouts/tress on 2003	480	130	521	140	531	140	555	150	540	150
No. sprouts on 2008	242	135	260	145	265	145	270	155	270	155
No. of sprouts/tress on 2013	120	138	130	148	131	149	134	159	135	155

: *M= managed; **U= unmanaged

(Source: References No. 3, 13, 17, 18, 20, 22, 28-32)

For the ease of studies, the study sites were numbered as follows: Selimaj-Lekurtaj (1); Gri-Velisht (2); Markaj-Rosuje (3), Margegaj-Shoshan (4); Kerrnaje-Hoxhaj (5) were located in Bujan Commune, Krasniqe Region (1,2,3); Margegaj Commune, Krasniqe Region (4); Gashi Region, Tropoja Commune (5). The selected five **managed** chestnut high forests were named as **Model: 1** consisting of HFM_1; HFM_2; HFM_3; HFM_4; HFM_5 (**$Model_1$**) and five unmanaged chestnut high forests for **control** (without intervention and left under nature-care as permanent plots) studies as **Control: 1** consisting of HFU1; HFU_2; HFU_3; HFU_4; HFU_5 (**$Control_1$**).

The study management was based on the agrosilvicultural models proposed by Lushaj[17;18] and Bourgeois[19], however adaptations depended on the local conditions and circumstances where the management system and agrosilvicultural treatments and all activities were carried out, occurred 25-31 years, respectively in natural zones, distributed from 300 (350) to 1,000 (1250) m a.s.l. in the chestnut forest, located across the district, named **Tropoja working circle** (agro-forest economy), in northeast of Albania.

Field surveys: The surveys in 1981 revealed the occurrence of blight disease, ink disease and yellow mistletoe infestations in the chestnut trees and were exposed to abiotic stress like drought and weathering conditions. The impact was severe on the aged branches that were dead damaged logs. The data were recorded as incidences (I) and severe incidences (S.I.) and % S.I. were calculated as per the studies conducted by Lushaj[17,18].

Management methodology/protocol: Thinning of the trees began in 1982, and rotation of tree removal was begun at five year interval and 2003 was the initiation of tree removal and completed[3,17] in 2008 and 2013. Wise agroforestry practices were implemented based on the severity of the damages in the chestnut trees. For the accomplishment of the research study, the project was divided into **eight stages,** each with an interval of 4-5 years. In the permanent plots, the following activities were taken up and implemented as per the details of Lushaj[17,18,20] and Bounous & Beccare[21]. Designing and conservation and improved treatments were taken up keeping in mind to develop and to show and to manage the sustainable programs as protocol/s as futuristic independent activities independent of the study team. **Table – 4** highlights the areas of activities strictly taken up, implemented, and considered as mandatory salient features.

Stage/phase activity: All activities were carried out, based on the activities of Lushaj[13,20,22] and Lushaj & Dini[3] and, as stage-by-stage for the ease of study and observations. The **first stage** was carried out between 1981 to 1982 with the inventarization of chestnut trees, removal of 90 % of old and abounded chestnut trees by razed full cutting to a shift from high chestnut forest into a simple coppice by the allowance of 15-20 chestnut trees per ha. And by 1983 (the end of **first stage**) about 10 % of chestnut trees were removed by razed full cutting to orchard maintenance with inventarization of sprouts/ every permanent plot.

The **second, third, fourth, fifth** stages were maintenance of simple coppice with relative brief rotation time, accomplished at every 5-year interval (during 1983, 1988, 1993 and 1998) with the aim of improvement of health status, grafting and stimulation of growing of chestnut crowns. At every stage 50 % of sprouts per ha were removed by means of agrosilvicultural treatments by fruit tree thinning. The **sixth and seventh stages** were simple coppices with relative brief rotation time, accomplished at interval of 5 years (during 2003 and 2008). In every stage 50 % of sprouts per ha were removed. Through these stages the principal aim was reached that is converting abandoned chestnut forests into simple coppices and simple coppices into orchards. The last, **eighth/final stage** was done in the beginning of the year 2013, the harvests of quality and quantity based chestnut trees.

Table 4: Highlights of the areas of activities strictly taken up and implemented

Salient features and works handled	
Help and support	Expert consultation and relevant stakeholders support taken
Implemented socio-economic practices	Foundation establishment; Mobilization and realization training of regional communities; Staff training for study as well as survey security; Systematic labor management as community activity; Maintenance of stack records, purchase records; Phytosanitary inventory within the plots for all chestnut trees; Observational study of health status (in terms of pathogenicity) of each and every tree in all 10 plots (scrutinization) and note of the trees for razor cutting; Timeframe for razor cutting of damaged and abandoned trees during the month of July or February in next year on annual basis; Regular activities of ground cleaning, pruning, planting, and or grafting, removal of sprouts etc.; Physical and mechanical removal of infested rams and ramules and thereafter burning (to check on further infestation); Application of copper sulphate (CuSO4) as treatment to cut ends of rams and ramules (to avoid if any) infestation; Regular and systematic planting of grafted sprouts; Systematic tending practices; Systematic rarefaction of fruit yielding trees; Possible potential by biomass energy; Increasing of the farm income; Ect.
Expected results (on sustainable grounds) as agroforest ecology and as business for profits	Conservation of high forest stands into simple coppice and from coppice into orchards, under systematic formats; Study and identification of local germplasm and their *ex situ* collection; Detailed studies of bio-forest-agronomics and quality traits in chestnut trees; Maintenance of each every aspect of study records; and collection and records of traditional knowledge's (TK), based community information's concerned to the forests; Coppice and orchards maintenance for sustainability chestnut; Fruit yield has increased to 8-9 times higher than in the year 1981; Biomass energy potential; Planting of new orchards were carried out cover 50 ha higher than in the year 1981; Watchtowers constructed; Increasing of the farm income to 15-20 times higher than in the year 1981; Ect.

(Source: References No. 3, 13, 17, 18, 20, 22, 28-32)

RESULTS AND DISCUSSION

Among the study sites (5 managed sites and 5 control sites) > 100 year old chestnut trees with infestations, yield of fruits reduced to av. 6 Kg/tree (of 1/10th of the regular yield), with disqualified characteristics as timber that were undergone severe abiotic stress and were of about av. 160 trees/ha were removed due to unsuitability for maintenance and study purposes apart from hindrances during orchard conversions. Several workers[3,15,23-28] have shown that the well maintained chestnut orchards that were transformed from simple coppices yield 8-9 times higher than the regular forest stand under agro-silvicultural practices.

Under **first stage** activity (during 1981-82) of inventarization, av. 140 trees (abandoned) were removed and that accounted to 90%. The remaining trees of av. 160 that were under high chestnut forest were maintained according to silvicultural practices into simple coppice and av. 17-18 trees were maintained as reserves. These reserves were full cutting razed by the end of 1983 making surplus area for av. 4,500 sprouts/ha in all the 10 study plots. During the **second, third, fourth and fifth stages**, the sprouts were grown into simple coppice and at every five year interval, the improvement in health status were analyzed. Graftings were taken up and stimulation of crowns was done by chopping. Fruit trees thinning were done by removal of 50% of the sprouts/ha that was av. 4025 and minimised to av. 2010 as per the protocols of silvicultural practices.

During the **sixth and seventh stages** were simple coppice maintenance with relative brief rotation time accomplished at interval of five years (2003 and 2008) with reduction of sprouts by 50% from 950 to 270 trees/ha in all the ten plots (of managed and control) to orchard conversions and the removal (thinning) trees were under profitable one in terms of fruit yield and timber growth. Under full productions of fruit yield and their after as timber encourages several services called externalities as shown by the works[10-12,21.] In the **eighth/final stage** of the project (during the beginning of the 2013), since its inception in 1981, the total number of young trees reduced from 240 to 270 and from 270 to av. 127-128 trees/ha in each of the ten plots under study that are fully grown and with high quality of timber and fruit yields due to the maintenances under agrosilvicultural practices[28].

As per the records of 1981 the severe infestations are controlled and reduced to 2-3% especially of chestnut blight canker (*C. parasitica*). Illegal cuttings were totally controlled with regular full-time farming care and protection rendered by the farmers. With the implementations of the wise and systematic agrosilvicultural practices, the numbers of trees fully grown with an av. age of 30 years of av. 127-128 trees/ha the fruit yield has increased to 8-9 times higher than[28] in the year 1981,. At the same time the use of natural and biological controls makes it possible to limit the damage caused to chestnut trees by this disease[29].

The authors after a crucial study on Tropoja chestnut massive with 2408.5 ha, lying in over 25 villages and a town of Bajram Curri suggest and recommend going in all chestnut massive for the conversion of an old, abandoned chestnut forest into simple coppice and coppice forest into orchards through the wise agroforestry practices and possible biomass energy cultivation of chestnut for sustainable renewable biomass energy as biofuels to harness not only electricity but also as gasification and as ready briquettes for cooking and water heating purposes. As of now, the Albanian Government is progressing with rejuvenation and reforestation programs with economically viable option. According the authors cultivation of chestnut has two other purposes as chestnut culture rejuvenation and soil rejuvenation and restoration by the enormous leaf fall that undergo natural decomposition to re-make of forest soils and to enter into faster reforestation programs by employing rural communities having tradition knowledge (tk) for economically sustainable cottage industrial programs for economic as well as socio-cultural improvements. The planting of new orchards were carried out cover 50 ha higher than in the year 1981. The estimated energy potential from biomass residues from chestnut and other cultures, and animal wastes was calculated at approximately 752.6 GW and 2709562.5 GJ respectively and of urban wastes

was calculated as approx. 6577815 Toe. However, these bulky organic residues must be re-processed back through aerobic composting and/or vermicomposting (rather than burning out) to feed back to the cultivable lands to enhance organic matter in the soil for the balance of soil-microbe relationships and thereby to enhance better harvests as has been the scenario in India. As of now farmers are not aware about using the renewable energy production as resources to increase farm income since they are also facing big challenges to produce food crops. Sustainability through cultivation of chestnut as renewable fuel biomass has been the current trend in Albania[30-32.]

CONCLUSIONS AND RECOMMENDATIONS

Five permanent plots received silvicultural practices like rarefaction (fruit thinning) and fully grown razed full cutting for profitability and total control of chestnut blight canker were shown as a possibility and in rare cases of 1-2% infestations considered as natural ecology. Illegal cutting were checked and under control. High quality in the timber ensured. The productivity of fruit yield were dependant on several factors like high forest, agrosilvicultural treatment (both managed and unmanaged sites), number or density of chestnut trees/ha, crown smoothening and infestation control. Thus, under wise and normal agrosilvicultural practices, in the region of Tropoja district, under orchard maintenance av. 127-128 trees/ha are recommendable of av. age of 30 years will be recommended. Thus the output of quality fruit yield of 8-9 times higher than the normal production can be guaranteed with international standard of timber stocking making way for services like externalities.

The rejuvenation of overmatured sweet chestnut (*Castanea sativa* Mill.) forests in Tropoja, Albania will be necessary, so the major objectives of suitable agroforest management of the chestnut in the present and future times will be, firstly, to rejuvenate the overmatured sweet chestnut massive by converting it from forest stands into an orchard for fruit and for timber production; secondly, to plant new orchards, thirdly to protect it, fourthly to use the estimated energy potential from biomass residues from chestnut and other cultures, and animal wastes, and fifthly to increase farm income. This means maximizing the productivity and quality of the chestnut trees to be harvested for fruit and for wood production and at the same time for numerous services, called “externalities”. A suitable agroforest management system of the chestnut and its use will be realised by means of fruit tree thinning, physical, mechanical, chemical and biological controls and other agroforest activities and at the same time to use the estimated energy potential from biomass residues from chestnut and other cultures, and animal wastes, and to increase farm income.

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*__Correspondence Author: Prof. Dr. Bashkim Mal Lushaj__; Institute of Geosciences & Energy, Water & Environment, P.O. Box 244/1, “Don Bosko” Street, No. 60, Tirana, Albania