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A Review Paper on: The Role of Agroforestry for Rehabilitation of Degraded Soil

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1. Introduction

The world population growth is steadily increasing and the situation is even more alarming in developing countries /third world continents. For instances, Ethiopia is characterized by a great bio-physical diversity, dividing the country in several agro-ecological zones, each with a specific fauna and flora. It therefore is an important centre of biodiversity and endemism (Zewge and Healey 2001). Due to the out going population (76 million) growth of Ethiopia (CSA 2008) and overgrazing and deforestation for agricultural activities, fuel wood and construction material, overall natural forest cover had decreased to a level of 2.5 percent of which only one twelfth has a dense forest structure (Zewge and Healey 2001). The combination of high endemism and fast habitat degradation in Ethiopia leads to a great risk of species extinction (Zewge and Healey 2001).

Poverty and natural resources/environmental degradation tend to negatively reinforce each other; that is, as the land is degraded, agricultural productivity is lowered, resulting in decreasing incomes and food security and vise versa (Eyasu 2002, Selamyehun 2004; Wakeneand Heluf2000). This has resulted in migration of rural poor to urban centers; increased cultivation of marginal lands; encroachment into forest regions; and depletion of land resource base of small holders (Demel*et al.,* 2000). Moreover, the country's topographic nature has made it more liable to degradation (Girma 2000). To overcome this problem, agroorestry has been proposed as one of the options for its positive influences on soil fertility, mainly due to tree components (Kamara and Haque 1992; Campbell *et al.,* 1994). The inclusion of compatible and desirable species of trees/woody perennials in agroforestry can result in marked improvement in soil fertility by: (i) increasing organic matter content of soil through addition of leaf and roots litter as well as other plant parts (Young 1997; Rao *et al*., 1998), improving organic matter status, which can in turn result in increased activity of micro-organisms in the root zone (Khanna 1998; Young 1997), (ii) enhancing efficient nutrient cycling within the systems (Khanna 1998), and (iii) controlling soil erosion (Young 1997; Rao *et al.,* 1998).

The objective of this seminar is to review the role of AF towards cease soil degradation.

2. Concept of Soil Degradation

Land degradation is a composite term; it has no single readily- identifiable feature, but instead describes how one or more of the land resources (soil, water, vegetation, rocks, air, climate, relief) has changed for the worse. On the other hand, according to Hurni (1993) the unhindered degradation of soil can completely ruin its productive capacity for human purposes and may be further reduced until steps are taken to stop further degradation and restore productivity.According to UNEP (1999), land degradation is the temporary or permanent lowering of the productive capacity of land. It is one of the biggest problems in the world particularly at third world countries, threatening the lives of millions of people in the humid, sub humid and dry lands, albeit/although at different levels Robert .J; *et al* (2008). Degradation commonly occurs when negative human activities become supplemental to the natural factors. The main human activities include overgrazing, over-cultivation, inefficient irrigation systems that do not correspond with soil water requirements and deforestation as well as industrial pollution, population increases is also the other drivers of land degradation (UNCCD 2003).

Erosion as one of a number of forms of soil degradation, including deterioration of physical, chemical and biological properties (Young 1989) all of which require attention. Therefore, the problem of soil erosion could be socioeconomic and/or environmental issue andit has become a global issue widely considered in management and conservation of natural resources (Morgan, 1995). More over, one of the main objectives of land resource management is aimed at soil conservation, since maintenance of integrity of soil quality, properties, process, and diversity is deemed essential to ensuring sustainable land use (Hurni, 1993). As well known land degradation has a vast side effect on the earth. The main consequences of land degradation, which impact negatively on human livelihoods and on the environment, are generally well known. They include**:** shortages of firewood and other wood, shortages of (NTFP) non-timber forest products (EFAP, 1994), increased sediment deposits, floods and land slides, drying up of springs and water bodies; siltation of dams, increased incidence of water-borne diseases, loss of biodiversity, climate change, desertification, all these reduce land productivity and affect food security (Robert.J *et al.*, 2008).

2.1 Soil Degradation impacts

2.1.1 Biological Soil Degradation

Biological degradation is frequently equated with the depletion of vegetation cover and organic matter in the soil, but it also denotes the reduction of biological activity (Hartemink andVan Kerulen, 2003). It is a direct consequence of inappropriate soil management that also results in physical and chemical soil degradation. It is known that soil fauna is an indicator of soil fertility status and influences the structure of the soil (Young, 1997). The destruction of soil structure by compaction, water logging or crusting, impedes aeration and thus the supply of oxygen to the aerobic soil organisms; conversely this is conducive to the anaerobic organisms (Mitiku *et al.*, 2006). To curb/control the biological degradation of the land the key strategy is making the land to be covered with desirable tree/shrubs.

Land degradation due to deforestation

2.1.2 Physical Soil Degradation

Physical degradation basically includes a negative impact on physical soil properties, such as structure, texture, aggregate stability, porosity, permeability (compaction), and crusting (Young. 1997; Mitiku, 2006). Soil erosionmay be considered part of this category because it physically reduces soil depth. Furthermore, soil compactionis an increase in bulk density due to external load leading to the degradation of physical soil properties such as root penetration, hydraulic conductivity and aeration (Morgan, 1995; Hurni, 1993). Compaction also usually occurs in mechanized farming systems, where the soil has to support regular heavy loads (true in developed). In the tropics damage due to compaction is thus a particular problem with forest clearance machinery and in agro-industry (Harteminkand Van Keulen. 2003). However, compaction can be triggered through grazing, even with low stock (Mitiku *et al*. 2004). All in all, these subject the land to physical degradation and resulted in reduction of the healthy of the land.

2.1.3 Chemical Soil Degradation

A number of chemical processes impair soil fertility, such as the depletion of plant nutrient reserves and enrichment of toxic substances (Hurni, 1993). As reported by Mitiku. H *et al* (2006) because of leaching, particularly in the humid areas, soluble nutrients from the root zone can be washed out. Acidificationproduces aluminum and ferrous oxides leading to phosphorous fixation, which is rendered unavailable for uptake by plants which are one of the implication of chemical degradation of the soil and human induced changes of hydrological regimes situation can degraded seriously (Hartemink and Van Keulen, 2003).

Organic matter ensures favorable physical soil conditions, including water retention capacity (Mitiku.*et al*; 2006). It furnishes balanced and slow-flowing sources of nutrients and is a basis for the cation exchange capacity (CEC). In cropping systems involving repeated tillage, there is rapid organic matterdecline, often within a few cropping cycles implies that organic matter decline is one of the chemical degradation of the land because organic matter is the key component for the growth of the plants and for productivity. Thus, one of the sustainable land management means is the reduction of the chemical degradation of the land, which is possible, only by tree/shrub based farming systems such as using agroforestry practices.

3. The Role of AF in Rehabilitation of degraded soil

As reported by Nair (1993) many factors of development in the 1970s contributed to the general acceptance of AF as system of land management, that it is applicable to both farm and forest. It has the potential for improvement in the physical, chemical and biological conditions of soils and thus the main advantage of AF systems is in their ability to bring favorable changes in all the three conditions.

3.1 AF on Soil and Water Conservation

AF has a potential for erosion control through the soil cover provided by tree canopy and litter, in addition to the role of trees in relation to the runoff-barrier function (Nair, 1993). The role of trees and shrubs in erosion control could be direct or supplementary. In direct use, the trees are themselves the means of checking runoff and soil loss. In supplementary use, control is achieved primarily by other means (grass strips, ditch and-bank structures, and terraces); the trees serve to stabilize the structures and to make productive use of the land, which they occupy. (Nair, 1993) and (Young, 1989) supported that leguminous trees have shown potential of reducing soil erosion through five principal ways: interception of rainfall impact by tree canopy, surface runoff impediment by tree stems, soil surface cover by litter mulch, promotion of water infiltration, and formation of erosion resistant soil structure. Udawatta *et al.,* (2002) reported that AF and contour strip had a combined significant effect on runoff, sediment, and nutrient loss reduction as compared with non-AF treatments. Similarly, Okigbo and Lal (1997) reported that the cover measure involving the use of vegetation for soil protection, maintains the hydrological balance in which the surface run-off component in the hydrological cycle would be minimized. In the same way, Juo and Thurow (1998) reported that vegetative barriers are generally used in combination with mechanical land treatments such as micro catchments. Thus, once the tree and grass species inside and around the micro catchments are established, a combined system of land treatments can increase infiltration and control of erosion. This could in turn improve physical, chemical, and biological attributes of the soil for fertility maintenance.

3.2 Soil Fertility Improvement through AF

In the broad sense, the productivity of the land is its suitability for production, the main components of which are light, water and soil. Young, (1989) defined soil fertility as the capacity of the soil to support the growth of plants, on a sustained basis under given condition of the climate and other relevant properties of the land. Regarding the soil fertility, Eyasu (2002) has reported that soil fertility comprises physical changes, which is the capacity of the soil to provide plants with foothold, moisture and air, and chemical conditions, which determine the capacity of the soil to provide plants with nutrients. Soil fertility decline results from the combined effect of lowering of soil organic matter, deterioration of physical properties, lowering of nutrient content, and in some cases acidification, that is commonly associated with the decline in soil fertility (Young, 1989). Udawatta *et al.,* (2002) reported that maintenance and enhancement of soil fertility is vital for global food security and environmental sustainability.

But, if measures are not taken on time to avoid the loss of soil fertility, it might be a headache to growingpopulation especially in developing countries. In line with this, Eyasu (2002) reported that declining soil fertility in tropical rain fed agriculture is becoming a serious problem for a growing number of people. Similarly, Kandji *et al.,* (2006) reported that low soil fertility is a major problem to food production and one of the key biophysical constraints to increased agricultural growth in sub-Saharan Africa.

To curb/control the problems of soil fertility, AF approach might play a positive impact.There are different types of AF practices that improve soil fertility management/ improvement: fallows, hedgerow, alley cropping, tree on cropland, plantation on physical structures. *Roa et al* (1998) reported that leguminous trees species have shown some potential for soil fertility improvement and soil conservation since soil fertility improvement can be achieved through biomass transfer, long/short term fallows, nitrogen fixation. In the same way, Ajayi *et al.,* (2008) reported that trees/shrubs improve the physical properties of soils. In particular, soil aggregation is higher in fields where trees are being grown, and this enhances water infiltration and water holding capacity of soils thereby reducing water runoff and soil erosion. It is also reported by Acharya and Kafle (2009) that leaf litters in AF systems enrich the soil fertility by providing organic matters, leaves control the speed of the raindrops and allow them to go down to the land surface slowly which helps water to infiltrate into lower part of the soil surface. AF systems have high potential in solving the problem of soil fertility when compared to non-tree/shrub based systems.Roa *et al*

(1998) stated that the maintenance of soil fertility in AF based systems could be achieved through increase or maintain nutrient status, increasing soil fauna and flora, better soil aggregation, lower bulk density, improved soil porosity, increase water infiltration had compared to the bare soil.

Soil Chemical properties under different tree species in parkland AF practice

No	Tree Specie	TotalNitrogen	Available Phosprus	Organic Carbon	AtRadius (m)	At Soil Depth (cm)
1	Faidherbiaalbida	0.50 ± 0.04 0.47 ± 0.02	98.64 ± 6.76 79.31± 7.09	5.78± 0.25 5.34± 0.27	1 10	0-40 >>
2	Croton macrostachyus	0.51 ± 0.01 0.48± 0.01	28.33±11.43 15.29± 6.27	4.08 ± 0.24 3.67± 0.28	1 10	0-40 >>
3	Cordiaafricana	0.51 ± 0.02 0.51 ± 0.01	68.85± 10.86 47.45±17.34	3.70 ± 0.31 0.3.89± 0.28	1 10	0-40 >>
4	Perseaamericana	0.47 ± 0.02 0.44 ± 0.02	98.90± 14.98 56.21± 15.34	5.16±0.17 3.78± 0.28	1 10	0-40 >>

(Gosaye Degu, 2010)

3.3 Implication to Sustainability

Reclamation agroforestry involves two stages. In the first stage, tree and/or shrub species are introduced on to degraded forestland together with any necessary mycorrhizal or rhizobialsymbionts, with the objective of checking erosion and restoring soil organic matter and fertility status. In the second stage, the cover may be selectively removed and agricultural production introduced (Young, 1989, Kessler, 1992). However, time is needed to build-up the enlarged plant-litter-soil nutrient cycle (Kessler, 1992), a period during which exploitation of the vegetative biomass should be kept low with necessary protection from grazing etc. The initial tree removal can be along contour aligned strips, with belts of trees remaining in between, leading by stages towards hedgerow intercropping (Young, 1989). Other options include fodder incorporation along strips or multi-storey systems (Young, 1989).

Rehabilitation of the world's degraded lands is important for several reasons. First, increasing crop yields is crucial to meeting the needs of the growing human population for food, feed, biomass energy, fiber, and timber (in the absence of a massive increase in the equity of global resource distribution (J. Perlin, 1993).Second, anthropogenic changes in land productivity have deleterious impacts on major biogeochemical cycles that regulate greenhouse gas fluxes and determine Earth's total energy balance (H.A. mooney*et al*, 1987). Third, biodiversity preservation depends, in part, on increasing yields on human-dominated land to alleviate pressure to convert remaining natural habitat (N. Meyers *et al,* 1983). Currently, land degradation is one of the paramount important require for the globe that is why the need is increasing to wards the solution. Bureshi and Tian (1998) reported that loss of soil fertility, soil erosion, and land degradation, has forced to search for more sustainable systems. AF as, a land use system is receiving greater attention in many countries to protect the land from various types of degradation. ICRAF (2004) reported that when land is scarce or when soil has a low fertility or is sensitive to erosion, AF technologies/ practices offer considerable benefits forthe long-term agricultural sustainability. Similarly, UNCCD (2003) stated that AF is a tool for achieving sustainable agricultural farming and improving the quality of life of the affected communities while simultaneously reversing the process of environmental and land degradation.

According to Young (1989) stated land rehabilitation using AF reclamation involves two stages. In the first stage, tree and/or shrub species are introduced on to degraded forestland together with any necessary mycorrhizal, with the objective of checking erosion and restoring soil organic matter and fertility status. In the second stage, the cover may be selectively removed and agricultural production introduced. Blay D *et al* (2004) also reported that as AF can be practiced in any of the ecological zones. It can be a way to reduce deforestation or land clearing and to increase crop yields (of food, fodder, fibers etc) and the diversity of products grown, but an additional benefit is the creation of a carbon sink that removes CO_2 from the atmosphere, or the maintenance of carbon in existing vegetation and, therefore, has implications for climatic change. (Roa *et al.*,1998; Nair, 1993;Young, 1989) reported that AF systems like improved fallows, contour hedgerows and other systems involving permanent cover play an important role in arresting and reversing land degradation via their ability to provide permanent cover, improve organic carbon content, improve soil structure, increase infiltration, enhance fertility, and biological activity throughthe provision of high biomass production, nitrogen fixation, a well-developed rooting system, high nutrient content in the biomass including roots, fast or moderate rate of litter decay, and other benefits of AF to successfully in improving soil properties.

AF involves management systems that incorporate a tree or shrub component in the agricultural landscape and it can increase both the carbon storage and biodiversity in areas where annual crops or degraded lands are predominant (YousifEi.A and Raddad.A, 2006). Young (1989) reported also as AF has shown promising results in the rehabilitation of degraded lands. With its low level of inputs and multipurpose-tree species focus, AF as a land restoration strategy also shows a significant potential for small-scale subsistence farmers in dry land and developing regions. The presence of trees in an agricultural system can have a significant influence by increasing the soil fertility and ecosystem production capacity as a whole. Although AF systems have been seen as a general solution for the reclamation of degraded lands, it is important to note that the ultimate success depends on the ability to increase the related knowledge among all partners involved and on the acceptance by farmers and local communities (Nair 1993).

How the Rehabilitation of Degraded Land could be Successful?

Apart from committed, sustained and proactive community participation in certain project activities that is focuses on rehabilitation of degraded lands other drivers of successful dry land rehabilitation programmes in denuded landscapes have been identified (Blay.D*et al*; 2004). The same author also mentioned some of solutions to make the situation successful:

- There should be some short-term benefits, whether monetary or material, in addition to anticipated future beneficial impacts;
- Local people's attitudes, behavior and perceptions should be in line with the principle of the rehabilitation programme – the people have to accept and internalize that change will be in the long-run be to their advantage;
- Comprehensive understanding of the interconnectedness, peculiarities and complexities of dry land ecosystems, especially dry land forests and woodlands;
- Rehabilitation should lead to improvements in soil fertility, hydrological processes, etc;
- Existing land uses should be analyzed, and land attributes should be matched with land uses so as to determine drivers of degradation.

3.4 AF Role at Ecology/Environment

In short terms the ecological functions of AFisto ensure maintenance of the ecosystem functions and global life support functions, including source/sink functions for greenhouse gases, filtering of water and pollutants, and maintenance of global geochemical (nutrient) cycles etc AF plays a positive role at balancing of ecology at micro/macro level.

To win a battle, the enemy must be known. In this case the enemy is land degradation and to win this the strategy ought to be planned. That is why Roger. R. and Leakey. B (2010) reported about the environmental problems in the dry lands of eastern Africa and forwarded the spiral of environmental degradation facing Eastern Africa (EA) dry lands is mainly anthropogenic in nature and origin. It is well known as AF plays a dramatically role at balancing of ecology/environment which is the current global issue and nowadays it is also the debating title for world leaders owing the matter of environment can control every things of the developmental issue. All increases in the carbon content of agricultural soils have beneficial impacts by reducing CO_2 emissions to the atmosphere. Longer-term and more effective sequestration occurs when carbon is stored in woody plants; hence AF has greater benefits than other farming systems. Studies suggest that through AF carbon sequestration could be increased from 2.2. up to 90-150 tones of carbon per hectare over a potential area of 900 million ha worldwide (Blay.D*et al*; 2004; Roger R. and Leakey's. 2010).

In AF, the incorporation of multiple species into production systems, intrinsically results in a high biodiversity compared to monocultures. In mono-cropping, ecosystems are extremely simplified by human manipulation to favor the production of a single plant species, creating unsuitable and/or unattractive habitats for most wildlife species. For intensive timber plantations often the same applies. AF systems, through multispecies and structural diversity, add complexity to agro-ecosystems, bringing them closer to nature. Such systems can be seen as interface between nature and agriculture, providing new niches and opportunities for wildlife that do not exist in monocultures. Various studies show that natural fence lines, windbreaks and intercropping systems act as important corridors for wildlife and show increased numbers of animals such as birds and insects and small mammals (Breman. H. 2001).

AF has also a positive role at enhancing of water quality and environmental amelioration. Agricultural non-point source pollution is a significant cause of stream- and Lake Contaminationin many regions of industrialized world. Roger. R. and Leakey. B. (2010) reported that the major causative source of this pollution is nutrients such as phosphorus and nitrogen that are lost from soils of fertilized agricultural and forestry operations. Recent studies have shown that AF practices such as silvo-pasture and riparian buffer could be a means of addressing the problem of environmental impact of nonpoint source pollution. The deeper and more extensive tree roots will invariably be able to take up more nutrients from the soil compared to crops with shallower root systems – the so-called "safety-net" effect that has been affirmed in various AF situations (Nair et al., 2008). With increasing realization of the adverse impacts of chemical agriculture and climate change on availability and quality of water in many parts of the world, water is now a critical issue in natural resource management. Time-tested integrated land-use practices such as AF could be appropriate approaches to addressing the problem.

In many parts of the world AF is primarily applied as a mean of erosion control. Breman. H (2001) reported from Netherlands are rather plane, water erosion is restricted to some small areas in the south. Wind erosion, on the other hand, is known to be quite severe in the northern Netherlands, such as the Flevopolders. Millimeters of topsoil are blown away every year, which means a loss of nutrients and often already scarce organic matter. Through the reduction of wind speed through trees, wind-erosion will be decreased, which indirectly will have its beneficial impact on the farm economy (Roger. R. and Leakey. B. 2010). AF has also good services on water purification. In doing so, tree-roots in AF systems can form a safety net, catching nutrients and pesticides, resulting in decreased groundwater and surface water pollution (Breman. H. 2001). Regarding the ecological foundations, AF systems have shown to provide several ecosystem services and benefits. In discussing these, it needs to be emphasized that the effects of many of these services and benefits cannot be measured in quantitative terms in relatively short time periods that are common for agricultural production systems.

When landscapes are increasingly being fragmented and remaining patches of natural vegetation are reduced to isolated habitat islands consequent to population pressure and human activities, mixed species AF systems could play a significant role in maintaining a higher level of biodiversity and provide greater landscape connectivity. Regarding the influence of AF on biodiversity conservation attaching with ecology Roger. R. and Leakey. B. (2010) indicated that AF impinges on biodiversity in working landscapes in at least three ways. First, the intensification of AF systems can reduce exploitation of nearby or even distant protected areas. Second, the expansion of AF systems into traditional farmlands can increase biodiversity in working landscapes. Third, AF development may increase the species and within species diversity of trees in farming systems (Nair et al., 2008). Another promising aspect of AF in the context of biodiversity conservation is in growing commercial crops such as coffee known as shaded-perennial systems in the AF systems (for instances south western parts of Ethiopia is good example of this).

Another the paramount important of the ecological point of view AF is granting the assurance for the sustainable land management which is the new approach to soil and water conservation. In this regards, there is an assumption which is reported by Mitiku. H *et al* (2006).

The assumptions are:

- population pressure is the fundamental cause for land degradation;
- poverty prevents small farmers from using adequate resources conservation techniques;
- farmers will only invest in soil and water conservation activities if land security is guaranteed;
- structural soil and water conservation measures are less attractive to small farmers because they have only long-term benefits;
- farmers do not adopt introduced soil and water conservation technologies because of their ignorance;
- ineffective indigenous and traditional practices result in further land degradation, famine and drought;
- and that poor farmers in general are less interested in conservation due to its long-term impact

These aforementioned assumptions are exaggerating the land degradation situation albeit/although it differs from place to place. AF has a great role at sustainable land management. Sustainable land uses are those land uses that produce public goods and services for consumption by the people while at the same time ensuring the protection of the natural resource base upon which those particular modes of production or land uses are anchored. AF can contribute to the evolution of sustainable land use in dry lands. This is possible because in the first place AF concerns about ecological and economic sustainability- resilience of environment, diversity of income. It is a system that merges production with ecosystem services. Jama B and Zeila A. (2005) dry land AF is aimed at increasing diversity of optionsavailable for mitigating the impacts of changing ecological circumstances and worsening economic environments, and is more stable than, mono-cropping or livestock rearing alone.

The intensive production of agricultural and forestry monocultures is unique to advanced developed countries, while worldwide the separation of agriculture and forestry has proven to be difficult. Up to present, AF has remained the primary land use approach in many parts of the developing world. Complex indigenous farming systems, producing a multitude of products such as timber, firewood, food, fiber, forage and medicines have operated effectively for centuries (Nair 1993). In addition to a multitude of products for direct use and/or sale, such complex systems offer a level of environmental protection (i.e. conservation of the natural resources) unmatched by modern land use technologies (Young 1989, Nair 1993) and regarding the sustainable land management Jama B and Zeila A. (2005) indicated that the link of production and protection forms the basis for the concept of sustainability, which is central to international development activities aiming to break the negative feed-back relationship between intensive land use and progressive environmental degradation.

3.5 The Services of AF at Socio-economic issue

Nowadays, at developing as well as advanced continents agriculture might be under pressure. Recent epidemics of animal diseases combined with government policies make it hard for farmers to make a living. As studies revealed that the Dutch farmers generally apply to two contrasting solutions. They either choose for a further intensification, specialization and mechanization or they prefer to extensive and diversify their farm income. AF could be a suitable option for socio-economic issue for different communities at different levels. AF gives farmers the opportunity to spread their income and risks over different products and with time (Jama B and Zeila A. 2005).

Furthermore well chosen AF combinations may result in a better spread and more efficient use of labor and machinery. At last, many AF systems and their products lend themselves for value adding activities. Also the demand for biomass production for fuel, fiber and waste management are expected to rise. The stronger the pressure on the price development of arable productions, the more attractive AF will become as an economic alternative to conventional farming. For instances, apart from diversification of income, AF systems may have direct economic advantages. It gives

landowners the opportunity to maintain a crop, while establishing trees on their land. Indirect economic benefits.AF practices may reduce the costs for labor and chemical input by suppressing weeds and pests. For example, the tree might be a host of predators of crop pests and the intercropping of tree alleys decreases the weed problem heavily compared to a pure forest stand. Trees in AF systems may benefit from the crop fertilization, weeding and irrigation increasing wood and/or fruit production. Animals often show to appreciate trees for their wind-protection and shade. Trees have a climate stabilizing effect and reduce wind-chill and heat-stress. As such trees not only contribute to the well-being of the livestock, but may also have an economic advantage (Jama B and Zeila A. 2005).

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