What are the local ecological, social and economic costs and benefits of agroforestry systems compared to conventional agriculture?

Luca Zehnder, Công Ly, Julia Mast, Leonie Buschmann, Pascal Vollgraff, Céline Gauye

Agroforestry is a land use form which aims at the conservation of natural resources by combining the plantation of woody plant species with conventional agricultural practices such as crop and livestock production. This results in a higher diversity of farm and forest products[1]. Agroforestry systems can be repositories for biodiversity, especially if they are in close proximity to diversity hotspots[2]. These systems form more diverse arthropod communities with higher numbers of predators and parasites which can function as a natural pest control[2,3]. Moreover the combination of different crops and trees can help control soil erosion and stabilize hillsides and terraces because woody species such as shrubs and trees reduce the surface runoff velocity[4,5]. This diversification has the ability to stabilize food security and income since it provides more opportunities than monocultures[6,7]. By-crops can even overcompensate the loss through lower yields compared to monocrop systems[8]. However, farmers often struggle with the implementation of agroforestry as it comes with profit uncertainties as well as higher work expenditure and complexity[9]. Therefore, farmers often depend on external support because initial costs are much higher than in conventional agriculture[10,11]. Additionally, establishing agroforestry systems is time consuming, which is why secure land tenure is crucial for the success of those projects[12]. Lastly, it is suggested that overall more species benefit from land sparing where areas of high-yield agriculture alternate with protected areas instead of land-sharing (e.g. agroforestry) where conservation and agriculture is in the same place[13].

Ecological costs and benefits

Luca Zehnder

Summary On the patch level agroforestry can protect soils from nutrient leaching[14]. On a wider scale it can improve water quality[5] as well as help stabilizing hillsides and prevent soil erosion[4]. In human dominated landscapes agroforestry helps to preserve a large proportion of biodiversity[15]. However, it is suggested that overall more species benefit when areas of high-yield agriculture alternate with protected areas (land-sparing) instead of land-sharing areas where the goal is to have conservation and agriculture in the same place[13]**.**

Agroforestry species of the Bolivian Andes: An integrated assessment of ecological, economic and socio-cultural plant values[4]

Where?

- Bolivian Andes

What?

- agroforestry with native species, use of native woody species in traditional agrisilvicultural systems such as hedgerow intercropping, barriers hedges, shelterbelts, silvopastoral systems

Why agroforestry?

- improving soil productivity, stabilizing hillsides and terraces, soil erosion control
- local species are adapted to traditional agro-pastoral land use and climate but they mustn't be perceived negatively in ecological (poisonous) or socio-cultural terms (e.g. death after planting)
- native trees are rarely cultivated nowadays → monoculture plantations of fast-growing exotic trees

are predominant (e.g. Eucalyptus) → criticized due to their allelopathic effect on crops and understory vegetation, depletion of soil nutrients and water, invasiveness
Why isn't it done/what are the prerequisites for it to be done?
- peasants must be able to derive socio-economic benefits
- agroforestry must provide favourable cost-benefit ratios → actor-oriented perspective
How can it be made attractive?
- focus on species with outstanding socio-cultural values → cultural keystone species

Reconciling Food Production and Biodiversity Conservation: Land Sharing and Land Sparing Compared[13]
Where?
- southwest Ghana and northern India
What?
- meet rising food demand at the least cost to biodiversity
- land sharing (both objectives on the same land) vs. land sparing (area with high-yield farming and protections areas where no conversion to agriculture takes place)
- analysis of crop yields and densities of bird and tree species across gradients of agricultural intensity
Results?
- More species were negatively affected by agriculture than benefited from it, especially species with small global ranges
- For both taxa (trees and birds), land sparing is a more promising strategy for minimizing negative impacts of food production (for current and anticipated future levels of production)
But:
- results are only valid under the assumption of being able to properly implement the two methods
- increases in crop yields do not guarantee land sparing and land sharing does not guarantee benefits to biodiversity → both approaches require careful design and implementation
- small sample of regions and taxa

Agroecological practices for sustainable agriculture. A review[14]
What?
- Different practices for sustainable agriculture such as agroforestry
Results?
- agroforestry reduces nutrient leaching, conserves soils
But:
- study estimates potential of agroforestry much lower than other agroecological practices. In addition to that, the integration in today's agriculture is and will remain low.

Agroforestry for ecosystem services and environmental benefits: an overview[5]
What is the paper about?
- Summary of different services and benefits agroforestry can provide
What is the potential of agroforestry?
- enhance soil fertility, reduce erosion, improve water/air quality, enhance biodiversity, increase aesthetics, sequester carbon -> classified into 4 categories: carbon sequestration, soil enrichment, biodiversity conservation, air & water quality

Agroforestry: a refuge for tropical biodiversity?[15]
What?
- Review that examines whether agroforestry has benefits for biodiversity and if so, how can agroforestry be made attractive.
Conclusion:
- agroforestry is useful for reducing land-use pressure and can help to preserve a large proportion of biodiversity in human-dominated landscapes
- The literature reviewed suggests that agroforests with less intensive management and high canopy

cover have high species richness and are more similar to neighbouring forest reserves than intensively managed agroforests with open canopies.

Ecological Benefits of Agroforestry Systems

Leonie Buschmann

Agroforestry systems can have a wide variety of ecological benefits over conventional agriculture and forestry[16]. Pest loads can be reduced and thus pesticide use can be kept very low[3]. In addition, agroforestry systems can decrease water runoff and soil erosion[17]. Nutrient cycling (specifically N) can also be improved in agroforestry systems[18], decreasing the need for chemical fertilizers. Agroforestry systems can be repositories for biodiversity, although here the exact species combination in the system is key[2].

Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis[16]
What: overview of (local) ecological benefits of agroforestry compared to conventional agriculture and forestry
Where: Europe
Methods: review of existing literature
Results: agroforestry has significant positive effect on soil fertility/nutrient cycling, erosion control and biodiversity (as compared to conventional agriculture and forestry)

The simplification of traditional vineyard based agroforests in northwestern Portugal: some ecological implications[3]
What: traditional agroforestry vineyards and vineyards converted to monocultures compared in the diversity of insects, disease incidence and pesticide loads
Where: north-western Portugal
Methods: farm surveys and interviews with farmers over 2 summers
Results: agroforest system has significantly higher insect diversity, and less insect pest and disease problems (due to higher number of predators and parasitoids controlling pest numbers)

Agroforestry systems and soil surface management of a tropical alfisol: - II: Water runoff, soil erosion, and nutrient loss[17]
What: Four different production systems, 2 of them agroforestry (hedgerows) compared in water runoff, soil erosion and nutrient loss in water runoff
Where: Western Nigeria
Methods: field experiment, over 5 years
Results: runoff and soil erosion are significantly lower on agroforestry plots, nutrient loss is inconclusive

Nitrogen dynamics of tropical agroforestry and annual cropping system[18]
What: 3 different maize production systems, 2 are agroforests (alley crops) which produce mulch as N source for maize compared in their soil N availability
Where: Costa Rica
Methods: Experimental plots, 8 years old
Results: addition of alley crops increased maize biomass production and N availability, suggesting that less fertilizer would be needed in a production system like this

Biodiversity conservation in traditional coffee systems of Mexico[2]
What: Five different coffee production systems, 4 are agroferests 1 is purely agricultural compared in their biodiversity (plants, arthropods, amphibians and reptiles, mammals)
Where: Mexico
Methods: review of existing literature
Results: traditional agroforest approaches have significantly more biodiversity, especially bird life
But: it's important to distinguish the type of agroforestry, biodiversity of shade trees is key

Economical costs and benefits of Agroforestry

Julia Mast

Abhängigkeit der Wirtschaftlichkeit von: Produktionspreisen, Direktzahlungen, jährlichen Kosten, Investitionskosten[19]. Die Wirtschaftlichkeit eines Agroforstsystems ist nicht in jedem Fall gewährleistet, Software für die Berechnung empfehlenswert[10]. Direct economic reasons are important for an implementation of a an agroforestry system[20]. Save money through the non-use of fertilizers and agrochemicals, and the diversification of income[21]. Agroforestry is less affected by market and price fluctuations than conventional systems[22].

Moderne Agroforstwirtschaft in der Schweiz[19]

Resultate einer Befragung von LandwirtInnen über Agroforstwirtschaft und Resultate zur Produktivität und Wirtschaftlichkeit von Agroforstystemen berechnet mit Computermodellen. System mit Vogelkirsch- und Wallnussbäume auf Grün- und Ackerland.

Abhängigkeit der Wirtschaftlichkeit von: Produktionspreisen, Direktzahlungen, jährlichen Kosten, Investitionskosten.

Wirtschaftliche Vorteile:

- Bis zu 30% höhere Flächenproduktivität als der räumlich getrennte Anbau.
- Langfristig gesehen sind moderne Agroforstsysteme konkurrenzfähig.
- Hohe Produktediversifizierung führt zu weniger Abhängigkeit von schwankenden Marktpreisen
- Die Ernte des Holzes kann auf Jahre mit guten Marktpreisen gelegt werden.

Wirtschaftliche Risiken:

- Tiefe Preise für Baumprodukte und fehlende Absatzmärkte für Hochstamm-Obst
- Skeptische Einstellung der Landwirte und fehlende Feldversuche mit Agroforstsystemen in der Schweiz.
- Hohe Pflanzungskosten in den ersten Jahren und beschränkte Einnahmen aus der Unterkultur.

Ökonomisches und ökologisches Potenzial der Agroforstwirtschaft[10]

Fallstudie in Niederbayern, Deutschland. Untersucht die Wirtschaftlichkeit eines Agroforstsystems. Nutzung des Softwaretool Paracalc.

Der Betrieb baute auf 15ha Fläche ausschliesslich agroforstliche Sonderkulturen an. Die Baumkomponente bestand aus dem Speierling, die Strauchkomponente aus dem Speierling und die Unterkulturen aus diversen Wildkräutern. Für die Ernte und Separierung der Hagebutten wurde in eine 178'950 Euro teure Maschine investiert. Nach sechs Jahren Produktionserfahrung trat der erwartete Gewinn wegen geringeren Erträgen und enorm hohe Fixkosten durch die Investition in die Erntemaschine nicht ein. Der Betrieb konnte nicht weiter bewirtschaftet werden.

Die Einsichten aus der Fallstudie sind die folgenden:

- Für Agroforstsysteme in Europa fehlen Erfahrungswerte.

- Es existiert daher eine grosse Preisunsicherheit.

- Bei der Planung eines Systems muss das Risiko der Preis- und Ertragsunsicherheit berücksichtigt werden.

- Unterkulturen sollten als finanzielle Absicherung dienen.

- Maschinen sollten gemeinschaftlich angeschafft oder ausgeliehen werden.

- Die Verwendung der Software Paraclac für die Wirtschaftlichkeitsrechnung ist empfehlenswert.

- Agroforstsysteme haben ein grosses Potential in den Bereichen Naturschutz, Tourismus, Erlebniswelt, Edukation und Gastronomie.

Comparing silvopastoral systems and prospects in eight regions of the world[20]

contextual factors such as geography, climate, culture, and markets affect silvopasture selection and implementation.

The differences in motivation behind the agroforestry are astonishing:

- Uruguay: reasons to have cattle in the forests: reduce the risk of wildfire and maintain good relationship with farmers

- La Pampa: Livestock in the forest is a low-cost livestock return.

- New Zealand/Patagonia: reduction of erosion and trees are used as shelter to protect pasture and livestock.
- USA: diversify the income. Agroforestry offers benefits of diversity and resilience to offset possible crop losses. Shade ameliorates the conditions for livestock.

- Argentina: diversify and improve the economic profits.

- Brazil: agroforestry provides constant cash flow (one of the most intensively managed agroforestry system in the world)

sometimes direct economic reasons are most important, but not always. But indirectly costs are always a factor to have agroforestry.

Organic Yerba Mate: an Environmentally, Socially and Financially Suitable Agroforestry System[21]

organic yerba mate planted in agroforestry systems (AFS) in combination with native tree species. 5% of the area of the province Misiones in Argentina is in yerba mate production.
The benefits of the organic yerba mate grown in AFS are:

- The farmer get higher prices and compensate extra work involved in organic practices. With the organic certification the companies get double or more the price for conventional export products. The companies apply the concept of value-based agricultural supply chains. This means they create and distribute responsibilities and rewards across the supply chain and operate at regional levels by producing high-quality food products. The consumer has a connection to the product and has the chance to learn about social and environmental issues behind the product.

- Companies with the value-based agricultural supply chain have a competitive advantage in the marketplace.
- Less erosion and soil exhaustion due to monoculture. -> increase of soil fertility

- Save money through the non-use of fertilizers and agrochemicals.

- Diversification of income.

Monetary benefits in a Southern silvopastoral system[22]

This paper compares a silvopastoral system with four different traditional monocultural system (soybeans, rice, cattle, pine plantation) in the southern United States. Especially the monetary benefits respectively the Land expectation value (LEV), the equivalent annual income (EAI), and the rate of return (ROR) are analysed.
Agroforestry is gaining acceptance across the United States. A landowner decides on the basis of his vision for the land, his experience with land-use options, his knowledge of potential economic returns, available markets and demand which system he/she applies.

The (economic) benefits of agroforestry are:

- habitat heterogeneity promotes floral and faunal diversity.

- production of multiple outputs increases the potential for profit.

- the risk on one investment is not that big through the multicomponent investment.

- Agroforestry is less affected by market and price fluctuations than the traditional monocultural systems.
- additional income through hunting leases is possible.

The conclusion is that agroforestry is an environmentally and economically feasible alternative to traditional land uses.

Economical Aspects

Pascal Vollgraff

The research shows that there is almost everywhere an agroforestry system which is beneficial from an economic point of view., but most of this research is looking at small farm systems and not into the "big producers". Also, it shows that if it's the goal of a farmer to produce a large amount of a single crop like bananas or cacao the agroforestry system performs worse in output than the monocrop system[8,23]. But if you consider that a farmer maybe can charge a higher price for sustainable grown cacao and sell the by-products from the agroforestry system, he can make more money this way than monocropping.

Stone pine (Pinus pinea L.): an interesting species for agroforestry in Chile[24]

The to the Mediterranean basin native Pine tree was used in different agroforestry systems (potatoes, oats, sheep, grazing) in Chile. The experiment was conducted over 5 years in a region with less than average crop yields. The results were that stone pine is a highly beneficial tree for agroforestry in this region especially if you compare the net present value of the systems to a pure stone pine plantation.

Effect of plant diversity on income generate by agroforestry systems in Talamanca, Costa Rica[23]

This study evaluated the effect of plant diversity on the performance of an agroforestry system. The study looked at five different main production goods bananas, cacao, fruits from high trees, timber and firewood. The study showed that for low strata plants like bananas and cacao an agroforestry system is not beneficial. For the other plants (high strata trees) agroforestry systems were beneficial and the income per plant increased. This suggests that in those cases the complementary between the plants was way bigger than the competition.

Emergy and economic evaluation of seven typical agroforestry planting patterns in the karst region of southwest China[25]

The karst region in southwest china is currently having a serious conflict between restoration of the decreased vegetation due to desertification and the traditional agricultural system. Seven different agroforestry systems were analyzed and compared to the for the region typical corn pattern. The economic evaluation showed that especially the PSGP system (pomegranate sheep grazing pattern) generates more income.

Cacao agroforestry systems have higher return on labor compared to full-sun monocultures[8]

The growing demand for cacao leads to a loss forest and biodiversity especially if the cacao grows in monocultures. Agroforestry would be a way more sustainable production system for cacao. The data shows that the average cacao yield in an agroforestry system is 41% lower than in a monocrop system. But through the higher price and the by crop yields a cacao agroforestry system has a higher return of labor than a monocrop system.

The economic potential of fruit trees as shade in blue mountain coffee agroecosystems of the Yallahs River watershed, Jamaica W.I.[26]

This case study focus on the economic benefits farmers could get if they used fruit trees as shade trees for their coffee plants. The result is that farmers could earn from 443$ to almost 1500$ more per hectare by using fruit trees.

Local social costs and benefits from land-based agroforestry systems

Céline Gauye

Agroforestry is a sort of diversification that increases the resilience capacity against changes[27]. It improves health status by maintaining a good water quality and medicinal plants[6]. The management of homegardens can stabilize household food security and income and therefore, improve people's livelihoods and quality of life, reduce poverty[7]. Agroforestry is also a well-adapted system to preserve or even increase the power of women in countries living mainly from agriculture[28]; cash, land accesses and time are limiting factors for women; agroforestry, could be a better opportunity for women than cash crops intensive agriculture[29].

Building livelihood resilience: what role does agroforestry play?[27]

Diversification, like agroforestry systems, can increase the resilience capacity against shocks (drought, inter-ethnic conflict, wildlife disturbance, disease, …). This resilience maintains a sustainable livelihood of the households over a balance of five capitals: financial, physical, natural, human and social.

The coming of age of agroforestry[6]

Agroforestry can improve the health status of the local communities. Associating trees with crops provides natural nutrients and reduces the use of chemical fertilizers and thus, reduce water pollution. Domestication of some tree species in agroforestry can limit the deforestation for medicinal gaols and assure a security providing medicinal plants.

Traditional homegardens and rural livelihoods in Nhema, Zimbabwe: a sustainable agroforestry system[7]

Homegardens: don't require large capital investments or working capital; can stabilize household food security and income against uncertainties of monocropping (self-sufficiency); can improve the family's nutritional status, health (traditional medicines are the only medicines that are affordable).

Understanding farmers' perceptions and the effects of shea (Vitellaria paradoxa) tree distribution in agroforestry parklands of Upper West Region, Ghana[28]

Among other things, this article aims to better understand male and female farmer perceptions of shea maintenance. To understand why this desirable tree species have been under threat in favour of commercialized farming. **Gender and agroforestry in Africa: a review of women's participation** Factors that are limiting for women to have access to agriculture management and decision-making. Men have more access to agroforestry information because it's leaded mainly from men. Agroforestry can empower women in agricultural sector. Collecting indigenous fruits can be a part of a solution against food insecurity, poverty and malnutrition that touch mainly women and children.

Barriers of Agroforestry

Công Ly

In tropischen Gebieten sind ökonomische Barrieren, sowie unsichere Landrechte, know-how, Bürokratie, Infrastruktur und ungleiche Machtverteilung starke Hemmschwellen für die Implementierung und Instandhaltung von Agroforstsystemen[12]. Vorteile von Agroforstsystemen werden in Form von Umweltschutz von allen Stakeholdern wahrgenommen. Jedoch fehlt eine klare Quantifizierung der Vorteile solcher Systeme und führt zu Unsicherheit[9]. Bauern werden hauptsächlich aus finanziellen Gründen motiviert[30]. Ausserdem sind die Gemeinschaften häufig auf externe Hilfe angewiesen[11]. In Europa spielen vorallem physischer und finanzieller Aufwand eine Rolle, sowie die bürokratische und Arbeitskomplixität[31]. Die Rechtslage scheint überall ein grosses Potenzial zu haben.

Reviewing Social Forestry Schemes in Indonesia: Opportunities and Challenges[12]
Untersucht Chancen und Barrieren von sozialen Forstsystemen. Identifiziert Barrieren und Chancen in Indonesien: Machtverteilung, Rechtslage, Soziale Konflikte, Profit als Treiber

How is Agroforestry Perceived in Europe? An Assessment of Positive and Negative Aspects by Stakeholders[9]
Befragung von verschiedenen Stakeholdern. Quantifiziert positive und negative Aspekte:Umweltschutz, Produktdiversität, management Probleme, Finanzieller/physischer Aufwand, Komplexität

Identifying the Determinants of and Barriers to Landowner Participation in Reforestation in Costa Rica[30]
Versucht Motivation der Bauern zu messen : externer Support, Geschichte der Plantage, Wasserregulation. Barrieren: know-how, Kosten, schlechte Erfahrung, Vertrauen.

Facilitating Smallholder Tree Farming in Fragmented Tropical Landscapes: Challenges and Potentials for Sustainable Land Management[11]
Beurteilt Landnutzungsbedingungen aus der sicht von Kleinbauern, und wie fördert man Baumwirtschaft?: Sichere Landrechte, externe Hilfe, Einbezug in Entscheidungsfindung, Soziale Struktur berücksichtigen (Einbezug von lokalen Respektspersonen)

Addressing Farmer-Perceptions and Legal Constraints to Promote Agroforestry in Germany[31]
Untersucht Wahrnehmung und legale Einschränkungen von Bauern: Rechtslage Einfluss auf Profit, Finanzielle Aspekte als Hauptreiber, admistrativer Aufwand, ökologischer Vorteil generiert nicht genug Einkommen.

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