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Nature, people and agriculture in southwestern Ethiopia

The interaction between small scale agriculture and the diversity
of organisms in mosaic landscapes.

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Illustrations by Anna Hedberg.

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Content

This booklet is a popular report of a research project in ecology and human geography (see page 27 and last page). The booklet has two sections. The first section introduces general topics (page 4-12) while the second section deals with specific results from the research project (page 13-25).





The interactions between people and nature are evident in agricultural landscapes where people are dependent on some plants and animals but distressed by others. The choice of management of the land has consequences for which species that will thrive and which ecological processes that will occur. **Upper left)** A retained tree provides shade for livestock. **Upper right)** Vultures feed on dead animals perhaps decreasing disease transmissions. **Lower left)** Different insect pests on coffee leaves. **Lower right)** Black pepper (*Piper capense*) is a valuable spice that could be collected in the forests.

People and nature

We humans are dependent on nature in many ways for our livelihood. We use fertile land to grow crops, fodder and grazing land to feed livestock, fuel wood for cooking and clean water for drinking. However, we also sometimes struggle against flooding, diseases or damage from wild animals on our crops. Farmers know all of these things better than most people.

The farmers' goal ...

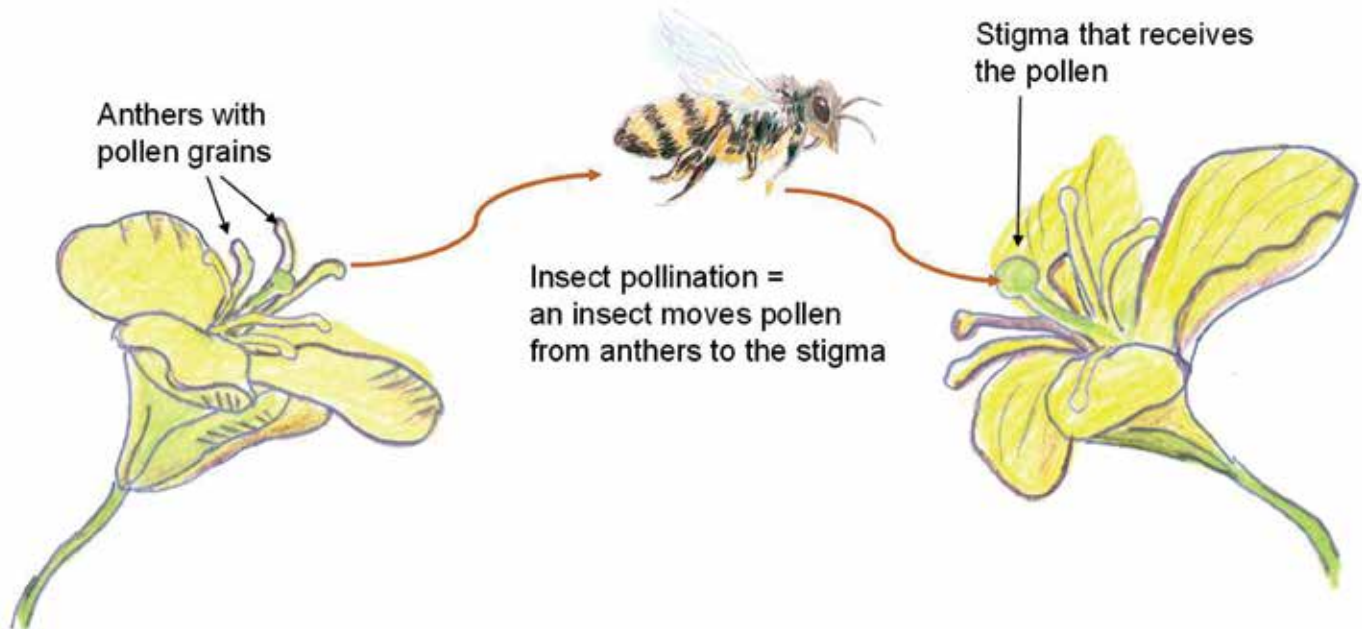
... might not be just high yields, but perhaps more importantly food security and some profit on sold products. Thus it could for example be as important to minimize the risks of crop failure as to maximize yield. Farmers not only plan for a sustainable production and a stable economy. Besides economic values they may also have other management goals including aesthetic or cultural values, for example flowers, certain spices, or a beautiful view. Other actors in the local community, the country or in the world might have yet other goals related to how the land is managed such as: conservation of wildlife, an even water flow in a river for irrigation, increased export etc. Sometimes such goals are conflicting to each other and sometimes there are possibilities for synergies.

Useful things ...

... that we get from nature are sometimes called “ecosystem services”. Many organisms surrounding us could be involved in the supply of ecosystem services, but some of them could also cause us harm. Since nature is complex it is not easy to understand how different organisms and processes affect humans at short or long time perspectives. For example, a hawk may catch and eat the farmers' chickens, which is bad for the farmers, but perhaps it also take a lot of mice from croplands which would benefit the farmers. The big carpenter bees bore holes in the wood the house is built from, but do they also enhance crop yield by transferring pollen between the flowers? Forests contain many valuable products, but are they also the homes for baboons that damage the crops? These are some of the many questions that we can raise and search for a deeper understanding of. If we can get answers on such questions it might help us to better manage the land, but also more clearly see and understand possible conflicts of goals. An increased knowledge about the nature and its interaction with people is one important component if we shall reach long term goals of food security, increased well-being and a sustainable usage of natural resources including the diversity of animals and plants.



Insects are the world's most numerous animals and are important for humans in many ways. **Upper left)** Bees are often regarded as the most efficient pollinators and there are numerous different species. **Upper right)** Bites of army ants are not fun at all! They come in big hordes and take whatever they want. Even if they could sometimes rob honey and wax from beehives, they most likely also reduce crop pests when they pass through a garden or a field. There are also other ant species that are predators and may play a role in controlling pests. **Lower left)** There are many types of spiders and almost all of them are eating insects, some of which are crop pests. **Lower right)** The abundance of crop pests can be reduced not only by animals eating them, but also if they are attacked by, so called, parasitoids. Parasitoids are small insects that lay eggs inside larvae of other insect species and kill them from the inside. Parasitoids are likely highly abundant in any agricultural system, but their biology is little known.



Many flowering plants including many crop species need a transfer of small grains (called pollen) from one flower to another in order to set seeds or to get larger seeds. This is called pollination. Some species are pollinated by wind and others by animals such as bees, moths and birds. Some crops such as mango, avocado, papaya and pumpkin need pollination, while others are partly self-fertile but produce more or better quality seeds if pollinated (e.g. rapeseed, green pepper, coffee). Maize, teff and wheat are all mainly pollinated by wind. A farmer growing a crop that needs animal pollination will normally get this ecosystem service from the various pollinators. However, the existence of the animal pollinators depend on the presence of other resources than crops in the landscape. Many questions are still unanswered or have only partly been understood. Which pollinators are pollinating which crops? Why are pollinators more abundant in certain places and less so in other sites? What management type can enhance pollinator services?

The role of forests and trees

Tropical forests are known worldwide for their richness of life forms of all kinds. The many different tree species are homes for numerous birds and insects, and even some plants are growing on the tree branches. In the moist and shaded conditions at the forest floor a variety of plants and animals could be found. Researchers have identified deforestation of tropical forests to be a major threat to many species of plants and animals both at local and global levels.

Forests ...

... can provide people with fuel wood, material for building purposes, spices and many other things. However, proximity to forests increases the risk of crop raiding by wild animals. Conversion of forests into agriculture is common, not least as a consequence of land scarcity. Thus, there may be a conflict in interest between those who want to protect the forest for its own values and richness of life and those who want to clear it for other purposes such as agricultural production. Important questions to ask in this situation could

be: Is it possible to keep certain forested areas only with the motivation that it is home for a variety of plants and animals? Which products can be taken from the forests without cutting the trees? Is the forest home to important organisms supporting ecosystem services for the surrounding landscapes? Does the forest have importance for the local climate and water supply to streams?

In the agricultural landscape ...

... there are often scattered trees, areas with grasslands, patches with less managed vegetation and so forth. Such variation is very important for the maintenance of a rich variety of plants and animal species in the landscape. Moreover, such non-crop areas could also be important for forest species when moving between forest patches. However, we know little about the importance of single trees or small forest patches for the provisioning of ecosystem services such as pollination and pest control.



It is not only humans that like maize or cabbage; also various small and large pest animals do. Farmers know this, but crops are not always easily protected. However, nature may support them because there are natural enemies of crop pests that may keep the damage at acceptable levels. Birds, spiders and insects eat many leaf eating caterpillars and other pest species. However, for many systems we have limited knowledge about which are the important pest controllers for the various pest species. We also need information whether the pest controllers actually increase crop yield by reducing the pests, and also what conditions that favor the natural enemies.



Trees could have many positive impacts in agricultural landscapes. They control erosion with their root systems. Some tree species also have an association with bacteria in the roots so that they can access nutrients (i.e. nitrogen) from the air and increase soil fertility and thereby increase the productivity. Such tree species are for example species of the genera *Acacia*, *Albizia* or *Milletia*. Trees are good to hang beehives in but are also nice places for small monkeys to hide in. There are numerous ways of using trees and their products and different type of trees provide different services. **Left)** The tree *Polyscias fulva* is commonly known as “the baboon’s chair”. **Upper right)** The tree *Albizia gummifera* is popular for shade and for hanging beehives in. **Lower right)** The flowers of the small tree or shrub *Vernonia amygladina* produce nectar and pollen for honey bees to collect.



In tropical agricultural landscapes there are many kinds of birds. Some people would just enjoy the diversity of their colors, songs and behavior. However, many birds could also be interesting from a farmers' perspective. Some birds such as flocks of seed-eating birds landing in a maize or sorghum field cause damage and hawks may make raising chickens a nightmare. However, birds also provide important ecosystem services. Birds of prey often take rodents while insect eating birds may reduce crop damage caused by aphids, caterpillars and other herbivores. Sunbirds are important pollinators, perhaps not for many crops, but definitely for many wild flowering plants. **Left)** African goshawk attack chickens. **Upper right)** Insect eating birds such as this Rüppell's Robin-chat can eat pest insects. **Lower right)** The Silvery-cheeked hornbill disperses seeds across the landscape but is also accused of robbing honey.

How do we get more knowledge?

Nature is complex ...

... and fascinating but it is also clear that farmers in particular and indeed all people are closely connected to the land, climate, different organisms and ecological processes. Different persons know different things and we need to learn from each other. For example farmers growing papaya have knowledge about when papaya produces fruit, while an expert on insects may know which species is the most important pollinator and what conditions that species need to fulfill its life cycle.

There are numerous questions ...

... that are still unanswered and researchers at institutes and universities try to find ways of finding answers to some of those questions. In the next section we present some results from a research project that has been ongoing in the two woredas of Goma and Gera in Jimma Zone, southwest Ethiopia during the years 2010-2014 (see also the back cover). Specifically we asked questions on how farmers are using forests and trees and how ecosystem services and problems associated with forests and trees are distributed across the landscapes.



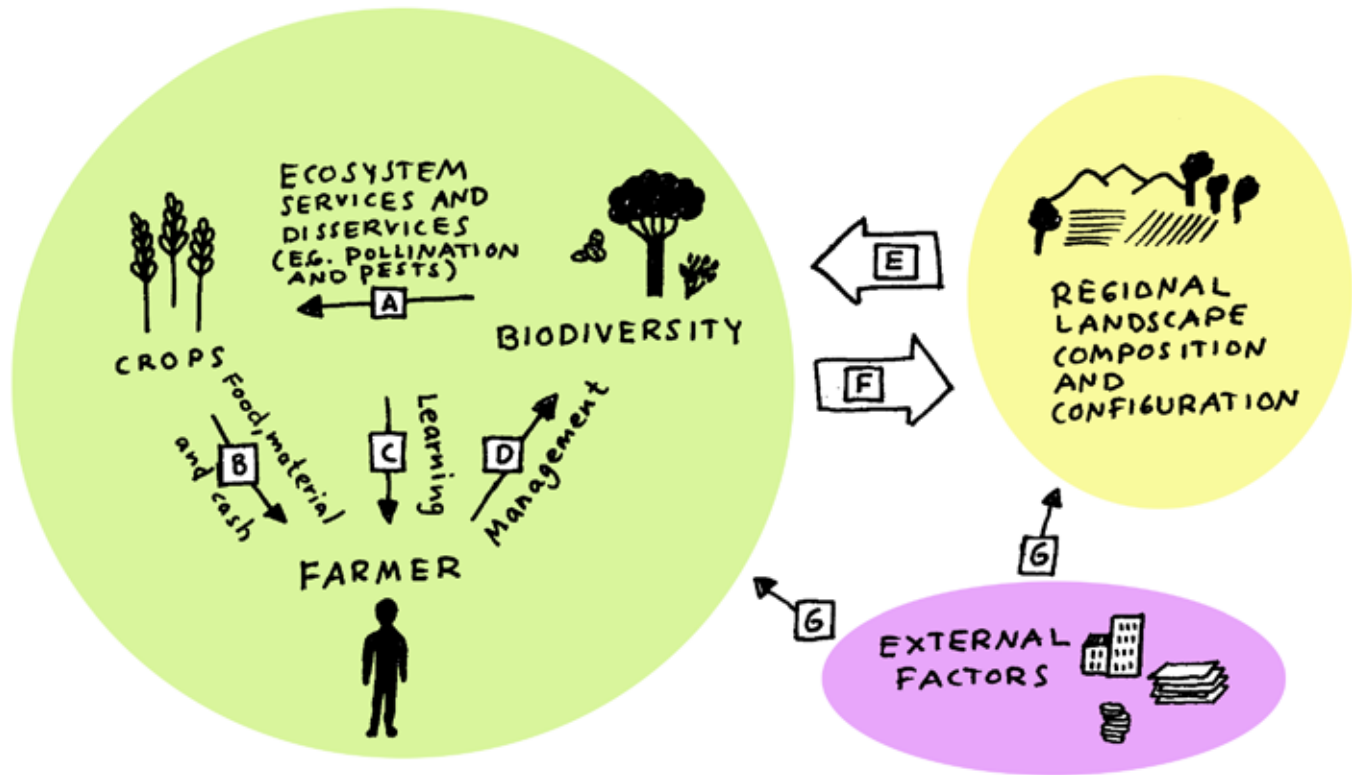
Crop damage by mammals is an obvious problem in many places. Baboons and bush pigs are often considered as the worst crop pests. Several other mammals could be annoying locally such as mole rats, porcupines and other monkeys. On the other hand, leopards in the forest may be the farmer's friend, since they kill bush pigs and baboons. There are also other mammalian predators that may consume large number of rats and mice from fields and gardens in the middle of the night. **Left)** Baboons. **Right)** Bush pig that is hiding in the forest.

People, biodiversity, forest, trees and agriculture in Gera-Goma, SW Ethiopia

The research project (see also back cover)

This project has been an interdisciplinary project where both ecologists and human geographers from Sweden and Ethiopia have collaborated to enhance the knowledge not only about nature itself but also about the

interactions between nature and people in an agricultural landscape. We have been working in southwestern Ethiopia. Most of the studies have been carried out in Goma and Gera woredas (districts) of Jimma Zone, but some studies cover larger areas across southwestern Ethiopia.



A conceptual figure illustrating the main focus of the project. (A) The biodiversity of the landscape can act on crops by enhancing and decreasing yields. (B,C) Farmers can learn about this and (D) decide on management actions. (E, F) All of this is happening in the context of a landscape and (G) external factors could also affect the system.

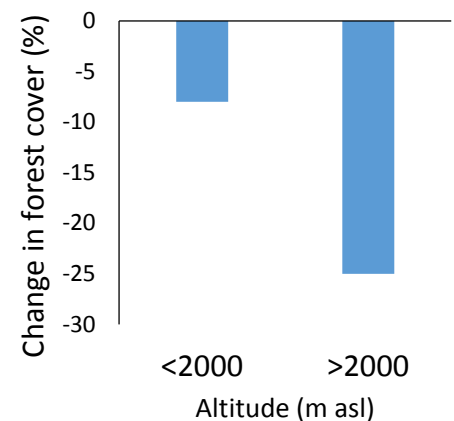


The study area in southwestern Ethiopia. **Upper left)** overview of SW Ethiopia. **Upper right)** The main study landscape with forests (dark) and agricultural areas (light). **Lower left)** Example of fields and tree cover in the agricultural landscapes. **Lower right)** A homegarden with various crops. **Upper left)** © 2014 Google, US Dept of State Geographers, Image Landsat. **Upper right)** © 2014 Google, Image © Digital Globe, Image © CNES/Astrium & © CNES/Spot Image, Lower left) © 2014 Google, Image © Digital Globe

Coffee is a key species for understanding forest cover change

During the last 40 years there has been a steady reduction in forest cover across this particular landscape from around 54% to around 40% as seen when comparing satellite images from these periods. The conversion of forest to open agricultural land has mostly occurred at altitudes above 2000 meter where coffee grow less well. At lower altitudes, coffee is often grown in the forests and forest margins and we suggest that this is an incentive for the farmers to conserve the forest. Coffee has for a long time been the most important cash crop in the

area, but is also consumed locally. Wild coffee could still be found in the deeper forests. Some people have moved to higher altitudes above the main coffee growing area to convert forests to agricultural land. In some places this has been a welcome activity by resident farmers since it might have reduced the problem of raiding mammals in fields further from the forest. According to farmers the raiding problems have increased during the last decade because of the banning of hunting of wild animals. (Read more in: Hylander et al. 2013; Ango et al. 2014).



Coffee is a main cash crop in the area and is an important driver of land-use and forest cover. **Left)** Coffee growing under the forest canopy. **Right)** The forest cover has decreased much more at altitudes above 2000 m than at altitudes below 2000 m; probably because coffee seldom grow above 2000 m and needs shade which increases the motivation of protecting forest and tree cover here (Read more in Hylander et al. 2013).

Why to keep or remove trees in agricultural areas

There are plenty of trees found scattered or clumped throughout the agricultural landscape. The most important reason why farmers keep dense stands of trees is to get shade for coffee plantations. Another reason to keep or plant trees is to maintain fences both to keep out cattle and to establish borders between properties. Fruit trees are also common, some of which entered the landscape rather recently. Some scattered large trees tell a story of previous deforestation and have been left purposely or by chance. Beehives are hung both in scattered trees, in patches of trees and in forests, and farmers consider trees that produce much pollen and nectar as valuable. The future of native trees

in the agricultural landscape is not secured. Many native trees are slowly killed by fire and axe and are replaced by fast growing woodlots of Eucalyptus. Another growing land-use type is khat fields, often situated inside homegardens with sparse shade. It is likely that the variety of plants and animals will decrease along with a decrease of native trees in the agricultural landscape. Such changes of the landscape must be understood both in the local context in relation to the nature, but also as part of a market economy with changing prices and top-down actions and regulations. (Read more in: Hedtjärn Swaling 2012, Ango et al. 2014, Dereje 2014).

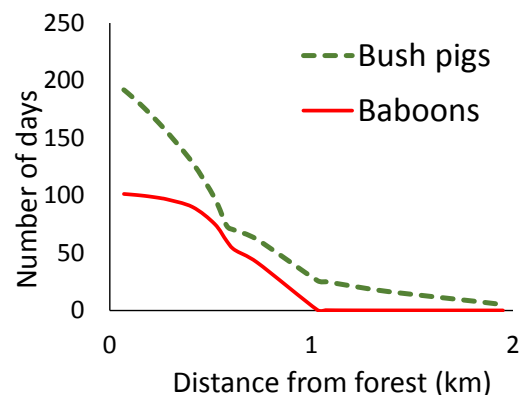
Living close to the forest

It is apparent that the frequency of crop damage by mammals is higher close to the forest than far away. The most commonly mentioned crop raiding animals are bush pigs and baboons. Many crops are affected and even coffee is raided by baboons. However, coffee grown more than 400 m away from a larger forest seem to not get raided by baboons. Despite these problems in living close to the forest, farmers have not adopted different growing practices. Farmers close to the forest grow the same crops in approximately the same frequency as farmers at some kilometers from the forest. Even if there are disadvantages with living close to the forest there might also be benefits. One important benefit is the close access to fire wood.

Other benefits of the forest for farmers can be that it is a good place for honey production, coffee production and other non-timber forest products. However, such benefits are only possible if the farmer has access to the forest and it is not occupied by landowners (e.g. coffee companies) that does not allow others to utilize these benefits. In our studies, we have not seen any strong benefits of being a farmer close to forest for pollination or pest control, but it is too early for strong conclusions, not the least since research at many places around the world have found such dependencies (see also below). (Read more in: Lemessa et al. 2013, Samnegård et al. 2014, Ango et al. 2014).



There are many reasons to keep or remove trees. **Upper left)** Khat is an increasing perennial crop that does not need shade and is little affected by wild mammals. It is often grown in homegardens inside live fences. **Upper right)** A cut tree close to the forest edge. Large trees that previously have been standing in the forest are frequently removed after they have been killed by for example fire. **Lower left)** Trees are often planted along borders of fields as live fences. **Lower right)** A traditional beehive on a tree. (Read more in Ango et al. 2014).

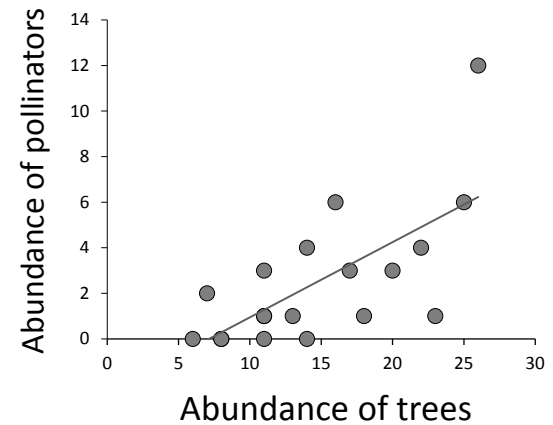


One commonly mentioned problem for farmers living close to the forest edge is that wild animals destroy their crops. **Left)** Focus group discussion with farmers. **Right)** Baboons and bush pigs visit homegardens close to forests many days in a year. However, the problems decrease with distance to the forest. Bush pigs reach about 2 kilometers in to the agricultural landscape from larger forest areas while baboons only reach 1 km. This difference might be because bush pigs are nocturnal and therefore are difficult to chase away (Figure modified from Lemessa et al. 2013).

The honey-bee and the others...

The honey-bee is an abundant species in this landscape due to the widespread practice of hanging bee-hives on trees. It is popular to hang beehives especially in the forest margin since there is an abundance of food sources in the many flowering trees more or less throughout the year. Honey-bees probably also need hollow trees and places to retreat to in the forests during periods with fewer erected beehives. Honey-bees are also the main pollinators of coffee in the area and the few days when coffee flowers, the plants are visited by an abundance of honey-bees. The data are quite variable, but honey-bee pollination of coffee most likely increases the yield compared to a situation without pollinators. There are hundreds of other wild bee species in the landscape, but for some reason they seldom visit coffee flowers. Ne-

vertheless, there are more wild pollinators in coffee sites with a complex and species rich shade tree community. Many different bee species visit homegardens across the landscape – certain species in the dry season and others in the rainy season. It seems like the species richness and abundance of bees is higher closer to forests than farther out in the landscape, even if we do not know if there is also a higher pollination efficiency closer to forests. However, when we manually added pollen to rapeseed flowers they produced more seeds. Thus it seems like there is a deficiency of pollination services in the landscape and more bees would therefore potentially be very valuable for farmers. (Read more in: Samnegård et al. 2014a, Dereje 2014).



There are many different species of pollinators in the landscape. **Upper left)** Carpenter bees are large bees that can fly long distances. Besides pollination they are also known for their habit of boring holes into wood, which could be annoying if that wood is your house! **Upper right)** The abundance of pollinators other than honeybees (i.e. other bee species and hoverflies) found on coffee is higher in areas with many trees. (Figure modified from Samnegård et al. 2014a). **Lower left)** We have put bags on plants to investigate the effect of excluding pollinators. **Lower right)** We took down one of the vane traps to see if we have collected any bees.

Fighters of the crop pests

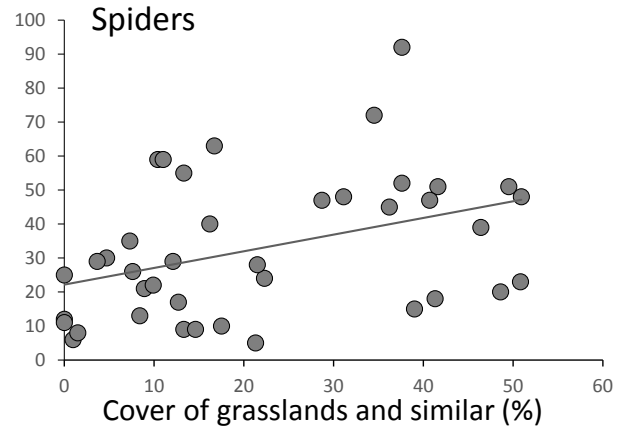
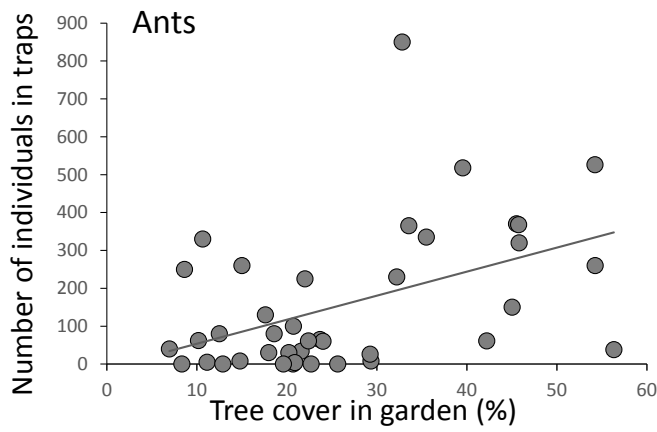
Crops could be attacked by various pests such as large mammals, tiny fungi or even viruses. In this project we have only been able to do a few things related to this large and important field. We have found that there are insect-eating birds that probably eat some of the larvae attacking crops, but it seems like spiders and insects probably are more important. The distribution of such pest-eating species in the landscape is somewhat complex but it seems like high tree cover is important for certain groups while high cover of grasslands is important for others. Probably the large variety of different land-use types found in our study landscape is providing many places with a high level of natural pest control. The

variation of pest attacks on coffee leaves and fruits did not show a consistent pattern across the landscape that could be linked to occurrences of natural enemies. However, we found several interesting patterns worth continuing to explore – e.g. that coffee rust had lower infestation rates in forests than in patches embedded in the agricultural landscape. In a pilot study we also found lower damage by leaf eating insects on coffee growing close to trees with ant-nests compared to on shrubs further away, which might indicate a positive role of ants in pest control. (Read more in Lemessa et al. 2014, Lemessa 2014, Samnegård et al. 2014b).

Species rich homegardens but unique species in the forest

The agricultural landscape in Goma-Gera districts is heterogeneous with many land-use types, crops and a large variation in tree cover. The species richness of many organism groups could be high in this landscape. For example around 60 bird species were observed on average in tree rich homegardens. We have also been able to get scientific names on many species of bees, ants, beetles and spiders that can be found in the homegardens. We also noticed that forests often hold many unique species that are not found in homegardens, such as certain species of plants and birds. We did not investigate the con-

trast between forest and agricultural land much in this project, but from other literature we know that many forest species need undisturbed conditions. Agricultural areas cannot compensate for this even if they are managed in a way ensuring high tree cover and heterogeneity. Thus if the goal is to conserve all species in a landscape it is important also to manage the forests so that they retain important habitats, structures and micro-climates. (Read more in: Engelen 2012, Hylander et al. 2013b, Samnegård et al. 2014a, Lemessa et al. 2014)



There are many species that potentially could be important for the farmers by eating crop pests. **Upper left)** The more trees in the gardens the more ants could be found; they might have a positive effect on crop pests. (Figure modified from Lemessa et al. 2014). **Upper right)** More spiders, which are also eating various crop pests, are found in homegardens with a lot of adjacent grasslands. (Figure modified from Lemessa et al. 2014). **Lower left)** We put up nets surrounding rape seed plants to investigate the effect of bird exclusion on the leaf damage on rape seed. We did this in 28 gardens to get as much data as possible; to repeat measurements is an important part of scientific research (Read more in Lemessa 2014). **Lower right)** We used small artificial larvae that should mimic real crop pests to investigate if birds and arthropods were eating pests in the gardens. Here is one such larvae that have been attacked by a bird.



Agricultural areas including homegardens could be rich in many kinds of species. However, undisturbed forests are homes also for unique species which cannot live in the open landscape even if there are many trees. **Upper left)** *Abyssinian oriole* is found only in the forest. To investigate how common different birds are we caught them in special nets and released them afterwards. **Upper right)** Many orchids are found high up in the trees and some could grow also in trees in the agricultural landscape (here *Polystachia sp.*). **Lower left)** Some butterflies are common in sunny areas while others are only found in the forest shade. **Lower right)** Many bryophytes and ferns are found only in forests, but some could be found in shaded gardens (here a moss *Leptodontium viticulosoides*).

What's next?

Research is quite a slow process since nature is complex and when you learn a new thing you also get a new set of questions. We have learnt much that was not known before this project started (see above) and are better equipped to ask a new set of important questions to move the field further. However, much is still needed before we can give specific advice on how to manage land to make better use of ecosystem services or to get synergies between a better life for farmers and a simultaneous conservation of the diversity of plants and animals in this region.

General advice based on ours and previous research around the world would still suggest that maintaining a variation of land-uses including some tree cover is a

good strategy to enhance the variety of life forms in the agricultural landscape that provide ecosystem services. However, the obvious struggle to keep various mammals out of the fields in the vicinity of forests highlight the potential conflict between farming and conservation of forests that needs to be handled.

We hope that this booklet will inspire you to learn more about farmers and other people's different interests and ways of using nature and and interactions between humans and nature. We hope that you have learnt something new and will also start to ask new questions which you had not thought of before.

Please join us in a life time learning process!



Left) A farmer that is glad for his wheat harvest. **Right)** Children are curious and curiosity is an important driver of science.

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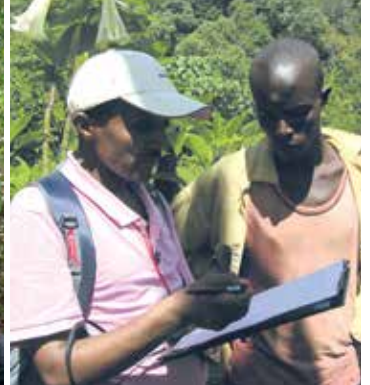
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Perhaps you have seen one or several of us when we have been collecting our data. We want to thank all farmers and their families for support and hospitality during these years. We also want to thank all other persons who have been participating in this project in one way or another! Thank you all for interesting discussions about our and your questions! Thanks to Dries Engelen and Julia Hedtjärn Swaling for comments on the text and sharing photos!

This project ...

... was an interdisciplinary project involving researchers from the discipline of both ecology and human geography. The project goals were to increase our understanding of how ecological processes regulate crop yield, how farmers use this knowledge to manage biodiversity that provide these services/disservices, and how these feedback mechanisms interact with regional landscape processes. Our main field work area has been the landscape west of Agaro, a small town in southwestern Ethiopia, which is a mosaic landscape with forests, forest patches and open agricultural areas. In the ecological part we have studied the distribution across this landscape of pollinators, pests, birds, arthropod predators, pollination and pest control. The human geography part has involved the study of farmers' knowledge of these processes and the rationales for their management and valuation of the land now and historically.

The booklet could be used to introduce topics for students at different levels in their education (high school as well as undergraduate students) as well as for practitioners in governmental or non-governmental organizations. The booklet is also available in Amharic and Afaan Oromo.

If you have any questions or want to get copies of the original scientific publications contact:



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This booklet ...

... is about “Ecosystem services and biodiversity in tropical agricultural landscapes” and is the final report written in a popular way from the research project “Examining mismatches between management and the supply of ecosystem services in Ethiopian agroecosystems across scales in space and time.” The project was financed by the Swedish government through SIDA and Formas to Prof. Kristoffer Hylander at Stockholm University in collaboration with Prof. Sileshi Nemomissa, Dr. Feyera Senbeta (Addis Ababa University), the late Dr. Getachew Tesfaye (Institute of Biodiversity), Dr. Ferdu Azerefehn (Hawassa University), Prof. Peter Hambäck, Dr. Lowe Börjeson and Dr. Peter Kinlund (Stockholm University).

Most of the work has been conducted as PhD-projects of Debissa Lemessa, Ulrika Samnegård and Tola Gemechu Ango. The following persons have made their master theses in the project: Julia Hedtjärn Swaling, Andreas Engelen and Konjit Dereje.



A cooperation between Stockholm University and Addis Ababa University