Green Corridors Identification, Design and Preparation of Guidelines

Principles and best practices for Green Corridor selection and establishment, and long list of proposed Green Corridors

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Client

The World Bank

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Cover picture: potential Green Corridor route in Jardaga Jarte Woreda, Oromia; (Satellite image: Bing maps)

TABLE OF CONTENTS

TABLES

FIGURES

ACRONYMS

AE	Area Exclosure/enclosure
BoA	Bureau of Agriculture
BR	Biosphere Reserve
BS	Back stopper
CBO	Community-based organization
CCHA	Community Controlled Hunting Area
CRGE	Climate Resilient Green Economy
EBI	Ethiopia Biodiversity Institute
EWCA	Ethiopia Wildlife Conservation Authority
GC	Green Corridor
GCCA	Guassa Community Conservation Area
MAB	Man and Biosphere
EFCCC	Environment, Forest and Climate Change Commission
ESA	European Space Agency
MoA	Ministry of Agriculture
NFPA	National Forest Priority Areas
NFSDP	National Forest Sector Development Program
NGO	Non-Governmental Organization
NP	National Parks
NTFPs	Non-Timber Forest Products
OFWE	Oromia Forest and Wildlife Enterprise
OSM	Open Street Map
PA	Protected Area
PFM	Participatory Forest Management
REDD+	Reduction of Emission from deforestation and forest degradation
RIP	REDD+ Implementation Program
RLLP	Resilient Landscape and Livelihood Program
SLMP	Sustainable Land Management Program
WDPA	World Database of Protected Areas

1 INTRODUCTION

Ethiopia hosts rich biodiversity, although much of it has suffered degradation and loss. The country is committed to improve conservation of biodiversity, which is witnessed in the recent pledge to restore 15 million hectares of degraded and deforested land (MEFCC, 2018).

Conservation strategies in Ethiopia combine the protection of biodiversity in and outside formally protected areas and restoration of degraded areas. The latter is receiving increasing attention.

The Sustainable Land Management Program (SLMP) is one of the major restoration programs implemented in Ethiopia in recent decades. Through the SLMP, Ethiopia has invested heavily in restoring hundreds of thousands of hectares of degraded and deforested lands in over 200 major watersheds. The installation of soil and water conservation structures, enclosures and afforestation/reforestation activities helped to restore and improve soil fertility, vegetation cover and ecological functionality, and the provision of ecosystem services and livelihoods.

The Resilient Landscapes and Livelihoods Project (RLLP), implemented in 152 SLMP watersheds, will complete and upscale best practices from SLMP, further improving climate resilience, land productivity, and carbon storage, and increasing access to diversified livelihood activities in the program watersheds.

The on-going conservation efforts need to be reinforced with new approaches and techniques that enhance biodiversity conservation and restoration. To that end the RLLP will establish Green Corridors (GC) that create connectivity between fragmented ecosystems. The GCs will introduce concept of landscape level conservation to the SLMP. However, GCs will have multiple functions including conservation of soil and water, pollution reduction, provision of wood and other products, and aesthetic values.

The Green Corridors (GC) will connect the program's micro-watersheds with each other and/or with existing areas of natural vegetation within the SLMP/RLLP macro-watersheds.

This report presents:

- The review of on-going biodiversity conservation and restoration efforts in Ethiopia,
- International experience with the creation of GCs,
- Guiding principles for GC selection, and
- Long list of proposed GCs.

2 REVIEW OF BIODIVERSITY CONSERVATION AND GREEN CORRIDOR CREATION

2.1 Ethiopia's experience with the conservation, management and restoration of biodiversity hotspots

2.1.1 Background

Ethiopia's diverse geography and climate gives rise to diverse ecosystems, plant and animal species. Around 10 different ecosystems, and 18 major and 49 minor agro-ecological zones exist in the country and are inhabited by a great diversity of species. Over 6,000 plant, 860 avian, and 279 mammal species are documented in the country, including many endemic species and genera. This diversity makes Ethiopia a globally significant region of biodiversity, recognized through the Conservation International's Biodiversity Hotspots. Ethiopia belongs to two hotspots found in the Horn of Africa.

Much of Ethiopia's biodiversity has been lost or severely degraded as a result of poor management practices and unchecked conversion of the natural ecosystems to other land uses (as much as 97% of the original vegetation in the highlands and 95% in the eastern lowlands).

2.1.2 Conservation areas in Ethiopia

Measures to manage biodiversity in Ethiopia combine the **conservation of primary** and the **restoration of degraded** ecosystems and habitats. Conservation is practiced in and outside formally Protected Areas (PA).[1]

Ethiopia's PA network covers about 100,000km (<10%) of the country. It includes strict conservation areas such as National Parks (NP), as well as areas which permit sustainable consumptive use, such as Controlled Hunting Areas. However, of the many PAs and reserves, only eight have been legally gazetted (UNDP, 2013).

Conservation efforts outside formally PAs include National Forest Priority Areas (NFPA), Biosphere Reserves (BR), Participatory Forest Management (PFM) and the preservation of traditional agroforestry practices.

National Forest Priority Areas (NFPA) were designated in the 1980s to conserve selected natural forests. Today, many NFPAs form part of PAs and BRs. The estimated 15,000 km^2 of PFM, mostly outside of PAs, cover natural and restored forests, and some plantations. BRs are a recent addition to Ethiopia's nature conservation areas. BRs and PFM aim to integrate sustainable development and conservation.

Figure 1 shows the conservation areas captured in the World Data Base on Protected Areas (WDPA), illustrating the overlapping categories and the focus of conservation areas in the less populated, southern half of the country.

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[1] Refer to Annex 1 for details.

Parks in the southwest and west of the country offer good opportunities for wildlife corridors within the country as well as transboundary conservation schemes with protected areas in Kenya, South-Sudan and the Sudan Republic. However, at the moment no concrete initiatives for larger corridors or transboundary management are known.[2]

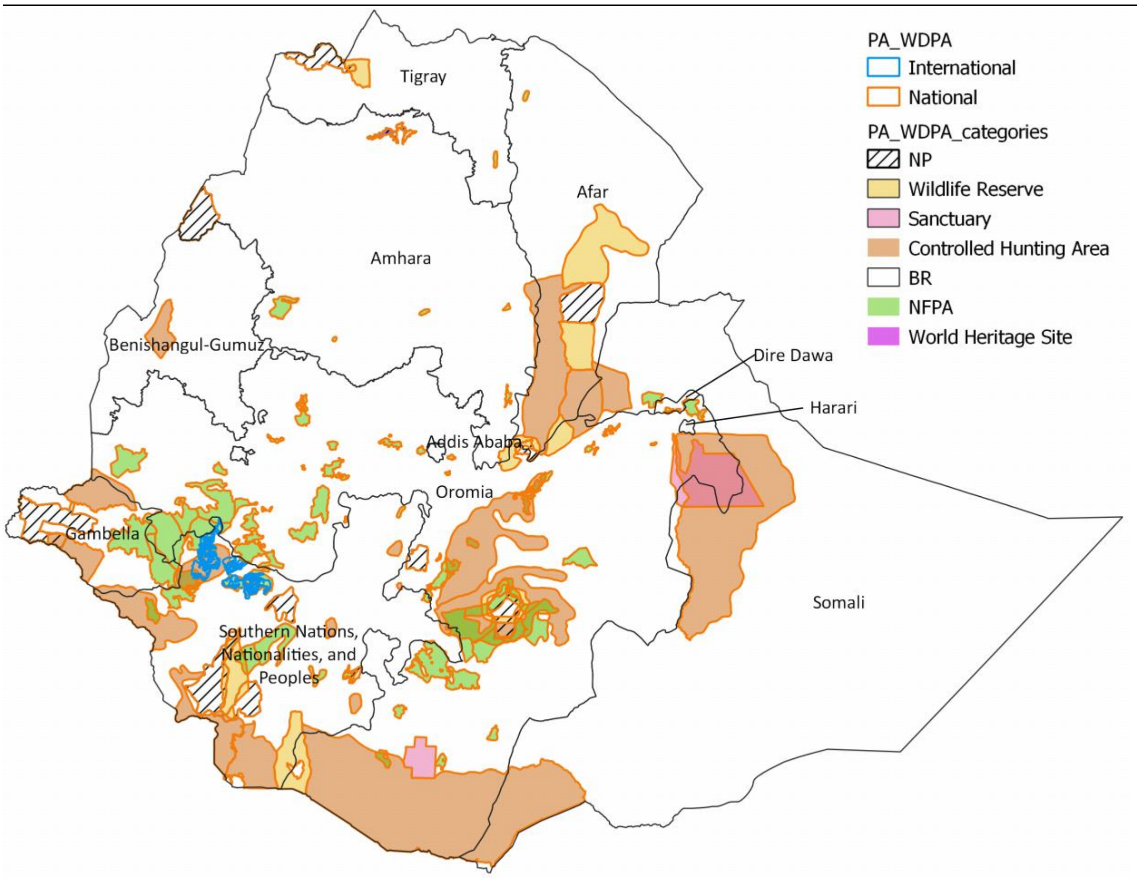


Figure 1: Conservation areas in Ethiopia

Source: WDPA, 2019 (not all PAs have been reported to the WDPA)

Different forms of traditional agroforestry practices exist in Ethiopia. Park land agroforestry, coffee shade agroforestry, multi-story home garden, and silvo-pastoralism are practiced in different parts of the country. These traditional land management systems provide refuge for a significant number of native flora and fauna.

Traditional agroforestry practices are most common in southern Ethiopia, especially in Sidama and Gedeo. In the southwest and west coffee is commonly cultivated under forest tree species. However, these management systems are under threat due to the growing population and rising demand for wood and food.

In northern Ethiopia, small Afromontane forests are found around churches and sacred sites. The “church forests” are considered to represent the original ecosystems but are often very small and completely disconnected from each other or larger forest areas. Aerts et al. (2016)

[2] Ethiopia submitted a proposal for the inclusion of the White Eared Kob (*Kobus kob leucotis*) in the Convention of Migratory Species in 2014 to secure international cooperation for conservation (CMS, 2014). GIZ studied the potential for corridors between Chebera Churchura NP and Kafa BR. (Bauer et al. 2016)

estimates that around 19,400 church forests exist in the Ethiopian highlands, with a total area of 39,000–57,000 ha forest. Surveys by Wassie et al. (2010) showed the high diversity of 168 woody species in church forests including 160 indigenous species. Similar to traditional agroforestry systems, church forests are visibly affected by encroachment for farming, grazing, and unsanctioned harvest of forest products (Woods et al. (2017) cited in Reynolds et al., 2017). Additionally, native species are gradually replaced by non-indigenous tree species such as *Eucalyptus spp*.

2.1.1 Institutions and policies for conservation

Protected Areas, although only partly gazetted, are managed by federal and regional governments. For the federally managed National Parks, the Ethiopian Wildlife Conservation Authority (EWCA), housed within the Ethiopian Forests and Climate Change Commission (EFCCC), is responsible. Some NPs, Wildlife Sanctuaries and Reserves, Controlled and Open Hunting Areas, and Community Conservation Areas are managed by regional authorities. Regional authorities are for instance the Oromia Forest and Wildlife Enterprise (OFWE), and the Amhara Environment, Forest, and Wildlife Protection and Development Authority.

The Ethiopian Biodiversity Institute (EBI) houses the national committee of the Men and Biosphere (MAB) program in Ethiopia. The EBI oversees the Biosphere Reserves (BR), but the mandate for the day-to-day management is that of regional governments and their lower structures. However, BR management still lacks a formally established and mandated government entity embedded into existing structures. Committees, composing representatives from various sector offices, are coordinating BR activities, but have very limited resources, frequent staff turnover, duty overlaps and lack of commitment hindering their effectiveness. Efforts are underway for organizational development and mainstreaming of the BRs into existing structures as well as Ethiopian legislation.

Forest management outside PAs is under the responsibility of the regional forestry authorities and the regional Bureaus of Agriculture (BoA). Federal bodies such as EFCCC and the Ministry of Agriculture and Natural Resources (MoA) have regulatory and overseeing roles.[3]

Other actors, in particular non-governmental organizations (NGO), are important drivers and implementers of conservation in Ethiopia. They are involved in PA management, restoration and sustainable management of forests and agricultural land. NGOs pioneered and are implementing the more innovative natural resource management approaches such as PFM, BRs and Area exclosures.

The key policies, strategies and action plans formulated to support the conservation and management of biodiversity resources of Ethiopia are listed in Table 1.

[3] The MoANR and its subsidiary organs at regional and lower administrative hierarchies are responsible for conservation and restoration of agricultural land.

Table 1: Policies and legislation for conservation

Topic	Policy / regulation	Details
Wildlife	Development, Conservation and Utilization of Wildlife in Ethiopia, Proclamation No. 541/2007	▪ Participation of local communities near conservation areas and private investors to in wildlife development, conservation and utilization ▪ Maximizing the economic and social benefit to be derived from wildlife resources as a contribution towards poverty reduction
	Ethiopian Wildlife Development, Conservation and Utilization, Regulation No. 163/2008	▪ Management of wildlife conservation areas ▪ Licensing for hunting and other uses ▪ Unlawful possession of wildlife products and harmful animals
Biodiversity	National Biodiversity Strategy and Action Plan (FDRE, 2005)	▪ Linking biodiversity protection and management to food security (poverty reduction), the improvement of health and livelihood especially of rural communities ▪ In line with the Convention on Biodiversity, in which Ethiopia is a party ▪ Aims to represent all ecosystems in Ethiopia to be conserved through a network of effectively managed protected areas ▪ Targets to bring all remaining natural ecosystems outside of the protected are under sustainable use management
Forests	Forest Development, Conservation and Utilization, Proclamation No. 1065/2018 Regional proclamations for Oromia, SNNPRS and Benishangul-Gumuz	▪ Acknowledges the multiple roles of the forest sector in Ethiopia (mitigation/adaptation to climate change, reverse environmental, social and economic problems associated with forest degradation/deforestation) ▪ Recognizes four different types of forest ownership: private, community, association, and state; encouragement for private sector actors and communities to participate in forest development, management and conservation.
	Draft national regulation for Forest Development, Conservation and Utilization	▪ Ratification by parliament is pending.

2.1.2 Conservation challenges and promising approaches

Despite considerable investments into the conservation and sustainable management of biodiversity by donor communities, the degradation and conversion of natural ecosystems inside and outside of PAs continues at a high rate.

The effectiveness of PA management is low, evidenced by missing or out-of-dated inventory data and management plans, encroachment of boundaries and settlement expansion inside the PAs, low involvement of stakeholders (local communities, civil society and international NGOs), poor coordination among sectors and weak law enforcement (Firew & Solomon, 2018). Furthermore, tourism is poorly developed, with few parks receiving significant numbers of tourists needed to generate the resources for park management and local livelihoods. Low support to international NGOs and private sector prevents investments in the framework of co-management agreements.

High pressure on natural resources by the growing population, very clear priorities across all sectors and government levels for economic development, and political instability contribute to the shortfall in fulfilling conservation (and restoration) targets as evidenced for example in Abijatta-Shalla NP (Box 1).

Box 1: Degradation of Abijatta-Shalla National Park

Intensive livestock grazing, and the expansion of farmland and settlements into parks are common in many PAs, amongst them the Abijatta-Shalla National Park. The park was established in 1970 to protect the Lakes Shalla and Abijatta. The NP hosts over 400 bird species, and fragile Acacia woodlands surrounding the lakes.

Livestock grazing in the park increased from just over 30,000 in 1971 to over 200,000 in 2010. People living in the park increased from about 9,000 in 1975 to more than 55,000 in 2015 (Fetahi, 2016). According to EWCA (2018), both livestock and human numbers have increased further since then.

Additionally, the water level of both lakes has been sinking due to uncontrolled use of water from tributary rivers for irrigation. Unless upstream water use is restricted, Lake Abijatta is expected to dry up by 2030 (ibid).

A monitoring assessment by Important Bird and Biodiversity Areas (2013) describes the park as “site in danger” and threat (pressure) score on the park as ‘very high’.* Today, visitors hardly see wildlife in the park, except from a few animals kept in a fenced enclosure near the park’s office, and fishing is not possible anymore.

Wetlands International, in partnership with EWCA, will assess the Economics of Ecosystem and Biodiversity and develop a management plan for the park. The involvement of the communities living in and near the park in planning and implementation is seen as key condition for the future conservation and restoration of the park.

* http://www.birdlife.org and http://datazone.birdlife.org/site/factsheet/abijatta-shalla-lakes-national-park-iba-ethiopia

However, cases of successful nature conservation exist in Ethiopia, providing valuable lessons learnt for future conservation and restoration efforts. These come from either community conservancies such as the Guassa Community Conservation Area (GCCA, Box 2) or from the participation of local communities in conservation, for example in PFM (Box 3).

Other successful conservation initiatives are linked to Community Controlled Hunting Areas (CCHA) such as those in the surroundings of the Bale Mountains NP. The local communities managing the hunting areas are organized into cooperates and generate considerable financial income from hunting. The economic incentive and byelaws adopted by the community allow effective protection from land conversion and degradation.

These examples indicate an ongoing paradigm shift in approaches to conservation, away from strict protection towards participatory management and benefit sharing. Recent policy reforms, accommodating community participation reflect this shift, e.g. in the recently endorsed Proclamation no. 541/2007 for ‘Development, Conservation and Utilization of Wildlife in Ethiopia, and Regulation No. 163/2008’ for ‘Ethiopian Wildlife Development, Conservation and Utilization’. Similar provisions are included in the revised forest proclamation (Proclamation No. 1065/2018). Nonetheless, the debate on the most suitable combination of strict protection and participatory approaches to sustainable utilization is still intense and on-going.

Box 2: Guassa Community Conservation Area

Guassa Community Conservation Area (GCCA) is found in Menz-Gera Midir Woreda, North-Shewa in Amhara Region about 260km north of Addis Ababa. It is an extraordinary area of biodiversity, and was formally gazetted as the Guassa Community Conservation Area in June 2012. The Guassa plateau offers a breathtaking view and hosts numerous endemic bird and wildlife species. It is an important remnant of Afro-alpine vegetation in the central highlands of Ethiopia and home to 26 different species of mammals, of which seven (23%) are endemic to Ethiopia (e.g. Ethiopian wolf, gelada, and Abyssinian hare)

The GCCA has the legacy of over 400 years of effective management through a common property resource system called "Qero", one of the oldest conservation management systems in Sub-Saharan Africa (Zelealem and Leader-Williams, 2005).

Derg abolished the Qero system, nationalizing all rural land in the country and disbanding local level land tenure and common property natural resource management institutions. This reform destroyed the functionality of the Qero system turning the Guassa area into an open access resource, resulting in in extreme decline of the integrity of the ecosystem.

After the fall of the Derg, the community reinstituted a similar system of governance (Zelalem and Leader-Williams, 2006), the Guassa Conservation Council. The Council composes representatives from 9 farmer associations (kebeles) with natural resource user rights and local government representatives. The council is responsible to oversee the management of the area, employing community guards for monitoring and prosecuting illegal users. The reestablishment of the communal management has helped to save and restore the Guassa plateau.

Box 3: Participatory Forest Management

Forests outside PAs are governed by weak formal institutional structures making forests prone to open access situation. Participatory Forest Management was introduced to Ethiopia in the mid-1990s to address this situation and the related widespread deforestation observed in the country. PFM soon proved itself to be an effective forest management scheme, with many donors and development partners supporting upscaling across the country. The federal and regional governments recognize PFM in forest policies since 2003. Today, about 1.5 million ha of forest are under PFM (Mulugeta & Habtemariam, 2014).

The formation of PFM groups is usually based on proximity and interest. Members can be organized in forest user groups or PFM cooperatives. Membership and the rules guiding forest use and management are laid down in the forest management agreement and plan. Commercial forest uses are restricted to non-timber forest products (NTFP) such as spices, coffee, gum, and bee-keeping. Group members are allowed to use timber and dead fuel wood for subsistence only. Commercial timber production has not been practiced and the law does not explicitly provide for it.

Forest management activities include enrichment planting, patrolling and regular monitoring for illegal activities. PFM is frequently linked to income diversification, value chain development (primarily improved marketing), as well as measures aiming at improved agricultural production and planting trees outside the PFM forest to offset any losses from reducing access to and use of forests.

PFM is delivering positive environmental impacts such as slowing down or halting deforestation, reversing forest degradation, and improving biodiversity conservation and water quality. However, PFM faces several challenges:

- The existing restrictions on timber utilization (especially where NTFP are less common) and poor NTFP based enterprise development make the financial sustainability of PFM unlikely. According to Aklilu et al. (2014) PFM impact on local livelihoods is falling short of expectations.
- The establishment and organizational development of PFM groups/cooperatives to a sustainable organization takes several years. Related, one of the key challenges of PFM is the need for financial and technical support and backstopping beyond the average project cycle of 3-5 years.
- High turn-over of government staff limits effective technical backstopping by the local authorities.
- Legal support to PFM groups in handling forest offenders is weak and conflict with land allocation to investors exist.

2.1.3 Restoration programs and approaches

Ethiopia is committed to restore 22 million hectares of degraded land, focusing on the restoration of degraded forest landscapes. This commitment includes 15 million hectares under the Bonn challenge and seven million hectares in the Climate Resilient Green Economy (CRGE)[4]. The targets align well with other national and regional policy frameworks designed in recent years, e.g. the National Forest Sector Development Plan (NFSDP), and REDD+ initiatives.

The Government of Ethiopia, in partnership with development partners, NGOs, and communities, has been designing and implementing a diverse number of programs to deliver on its restoration commitment, including:

- Sustainable Land Management project (I & II),
- Resilient Livelihoods and Landscapes project (RLLP),
- National REDD+ initiative and the REDD+ Investment Program (RIP),
- National Forest Sector Development Program,
- Biodiversity and Forestry Program,
- The Oromia Forested Landscape Program, and
- The Productive Safety Net and Household Asset Building Program.

Restoration programs commonly apply four approaches to restore biodiversity, productive capacity and ecosystem functionality of degraded landscapes, often in combination:

- Area exclosure,
- Soil-Water Conservation measures,
- Afforestation and reforestation, and
- Participatory Forest Management.

[4] Restoration and sustainable management of seven million hectare of forestlands, including 3 million ha of reforestation and natural forest management respectively, and 1 million hectare of rehabilitation of degraded forests

Table 2: Restoration approaches

Approach	Purpose and starting point	Restoration techniques
Area exclosure	▪ Rehabilitation of communal land for ecosystems services and future sustainable use ▪ Degraded land with remnants of natural vegetation or good stock of seed banks ▪ Applicable in a wide range of ecosystems, but mostly used in dry lands	▪ Natural regeneration in combination with – Physical soil & water conservation structures – Enrichment planting with pioneer shrub and tree species to improve soil and micro-climate
Soil & water conservation measures[5]	▪ Reducing soil erosion and increasing improving stream flow ▪ Applied on degraded lands with slopes >5% and gullies.	▪ Physical soil & water conservation structures (e.g. terraces, stone bunds) and/or ▪ Biological measures (e.g. alley cropping, grass bunds)
Reforestation	▪ Restoration of degraded land and forest ecosystems and provision of forest products ▪ Suitable mainly for humid highland environments ▪ Deforested sites or severally degraded forests	▪ Planting of trees ▪ Can be implemented in combination with area exclosure and physical SWC structures
Participatory Forest management	▪ Improving the management of natural forests and restored ecosystems ▪ Forests in the vicinity of settlements (susceptible to degradation) ▪ Restored watersheds (within area exclosures and/or after reforestation)	▪ Management plans specifying users, uses and zoning ▪ Enrichment planting ▪ Sustainable use of NTFP (e.g. coffee, spices) ▪ Restriction of fuelwood and timber use

[5] Structured SWC activity began in Ethiopia during the1970s. A number of nationwide SWC initiatives, supported by multiple donors, have been undertaken and are on-going since then, e.g. the Food-for-Work (FFW) (1973–2002), Managing Environmental Resources to Enable Transition to more sustainable livelihoods (MERET, 2003–2015), Productive Safety Net and Household Asset Building Programs (PSNP-HUB, 2005–present), Community Mobilization through free-labor days (1998–present), and the Sustainable Land Management Project (SLMP, I & II 2008–present) and Restoring Livelihoods and landscape Program (RLLP, 2018- present)

2.2 Green Corridors for biodiversity conservation: concept and experiences

2.2.1 Background

Increasing loss and fragmentation of natural ecosystems continue to threaten biodiversity at a global scale. Among measures taken to counter the threat is the establishment of corridors to reconnect fragments.

Corridors are a conservation model developed in the 1970s and have been applied since then with the broad aim of maintaining the integrity of environmental processes at landscape scale. They have been increasingly included in biodiversity conservation programs worldwide.

The term "corridor" is used to describe many different kinds of measures to create linkages among fragmented habitats. Many terminologies are used interchangeably to describe it, although most of them may not exactly mean the same thing. Some of the terminologies widely used include: linkage, wildlife corridor, green corridor, ecological corridor, biological corridor and landscape connectivity. These terms are used to indicate the general principle of maintaining or enhancing ecological coherence or connectivity across landscape of variable spatial scale; i.e. local to regional. In this and subsequent documents, the phrase "green corridor" will be applied consistently.

Green corridors are defined as linear vegetated features, either continuous and non-continues, established to ensure functional linkages between sites to maintain or restore a degree of coherence/connectivity in fragmented ecosystems (Bennett & Mulongoy, 2006).

Linking isolated patches of habitat with green corridors can help to increase the viability of local species populations by facilitating dispersal and genetic exchanges by either facilitating seasonal migration or regular and irregular movement of dispersers. It also secures the integrity of physical environmental processes that are vital to the requirements of certain species (such as periodic flooding) (Jongman & Troumbis, 1995).

Corridors vary enormously in scale as well as forms. In general, three broad kinds of ecological corridor can be distinguished (Figure 2):

- Linear corridors (such as a hedgerow, forest strip or river)
- "stepping stones", i.e., an array of small patches of habitat that individuals use during movement for shelter, feeding and resting
- Various forms of interlinked landscape matrices that allow individuals to survive during movement between habitat patches.

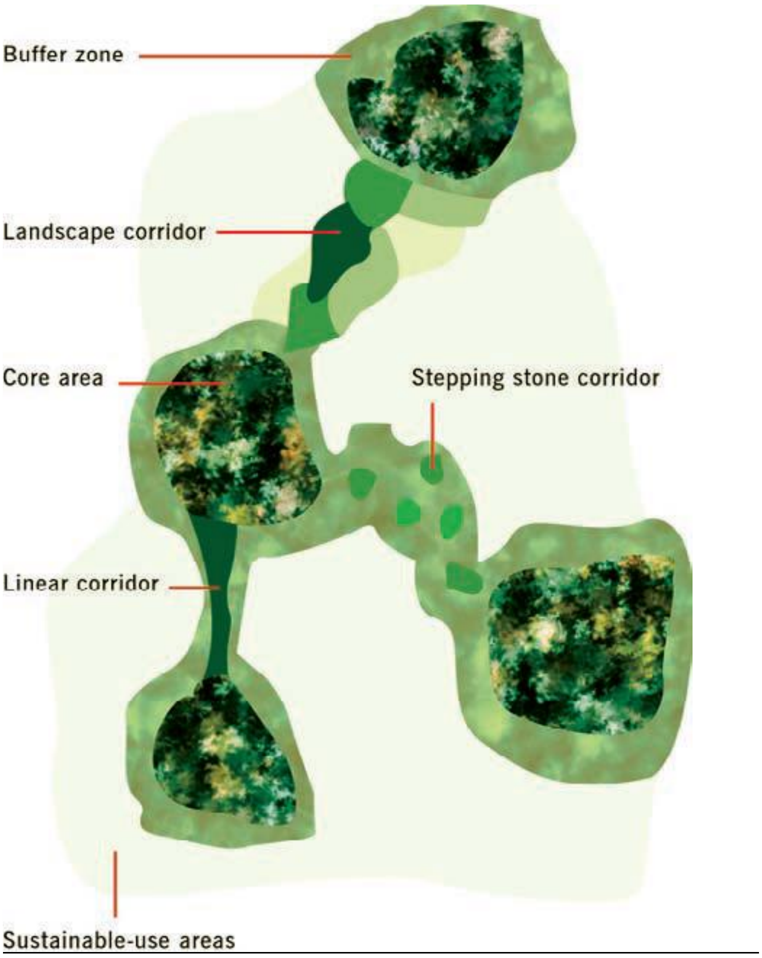


Figure 2: Possible spatial configuration of ecological network
Source: Bennett and Mulongoy, 2006

2.2.2 Experiences with Green Corridors

Green Corridors[6] are commonly defined as linear strips of vegetation which are different from the surrounding landscape. Their function is to conserve soil, water, plants, wildlife, or fish resources (e.g. USDA, 2004).

Documented case studies (e.g. ibid; IUCN, 2007) show the strong focus of corridors on increasing wildlife habitat and enabling wildlife movement. Nonetheless, the objective of corridors can be put more broadly: it is to maintain and/or restore ecological functions at landscape or watershed level.

Green corridors can be classified according to their purpose, origin of vegetation, and scale as listed in Table 3.

Table 3: Green Corridor classification

Purpose	Origin	Scale and elements
Conservation/enhancement of: ▪ Biological diversity ▪ Water resources ▪ Agriculture and wood production ▪ Recreation ▪ Community and cultural cohesion ▪ Adaptation to climate change	▪ **Natural habitat**, e.g. riparian vegetation along streams ▪ **Remnant habitat**, i.e. patches of natural forest, woodland, or other natural ecosystems which resulted from changes and disturbance to the surrounding environment. ▪ **Regenerated or planted habitat**, i.e. a strip of vegetation that was formerly cleared or disturbed, e.g. roadside vegetation, hedges, or windbreaks	**Local (~ 1km):** hedge- and fencerows, streams, roadsides, forest corridors, underpasses **Landscape (1 – 100km):** rivers and associated riparian vegetation, ridgelines, other broad links between reserves **Regional (> 100km):** major river systems or mountain ranges

[A] The actual benefit of ecological networks to mitigate the impacts of climate change on species population remains to be confirmed. (Bennett et al., 2006)

Source: Bennett, 2003

Green Corridors have been established in the framework of large ecological networks at national and regional level on all continents.[7] These initiatives started in Eastern Europe, about 40 years ago. However, the implementation in Europe and globally started to take off only in the 1990s.

Most pioneer works in developing and establishing ecological networks comes from Central and Eastern Europe in the 1980s. The first initiative to establish what is now recognized as an ecological network was the Estonian Network of Ecologically Compensating Areas (Külvick, 2002). At around the same time, several other countries in the region developed proposals that were based on the landscape-stabilization approach, most notably Lithuania and the former Czechoslovakia.

The Pan-European Ecological Network, born out of the above country specific experiences, is the most ambitious international ecological-network program. It comprises 52 Eurasian countries, which endorsed the Pan-European Biological and Landscape Diversity Strategy in 1995 (Pan-European Ecological Network, 1996). The aim of network is to ensure the:

- Conservation of the characteristic ecosystems and the natural habitats and landscapes of European importance across their traditional ranges;
- Sustainable use of semi-natural habitats and cultural landscapes of European importance;
- Maintenance of viable populations of species of European importance across their traditional ranges; and
- Maintenance of the environmental processes on which these ecosystems, habitats, species and landscapes depend.

[7] Corridors have also been established independently from larger networks, especially in urban settings or across large linear infrastructure in developed countries. Such cases were not included in the review, as they are of little relevance in the project context.

These objectives are to be achieved through the establishment of an ecological network that comprises three functionally complementary components:

- Core areas that provide the optimum achievable quantity and quality of environmental space;
- Corridors to ensure appropriate interconnectivity between the core areas; and
- Buffer zones to protect the core areas and corridors from potentially damaging external influences.

Based on the framework many countries and regions within countries have developed ecological networks. Lithuania is one of the pioneering countries to apply ecological networks, called Nature Frame (Figure 3).

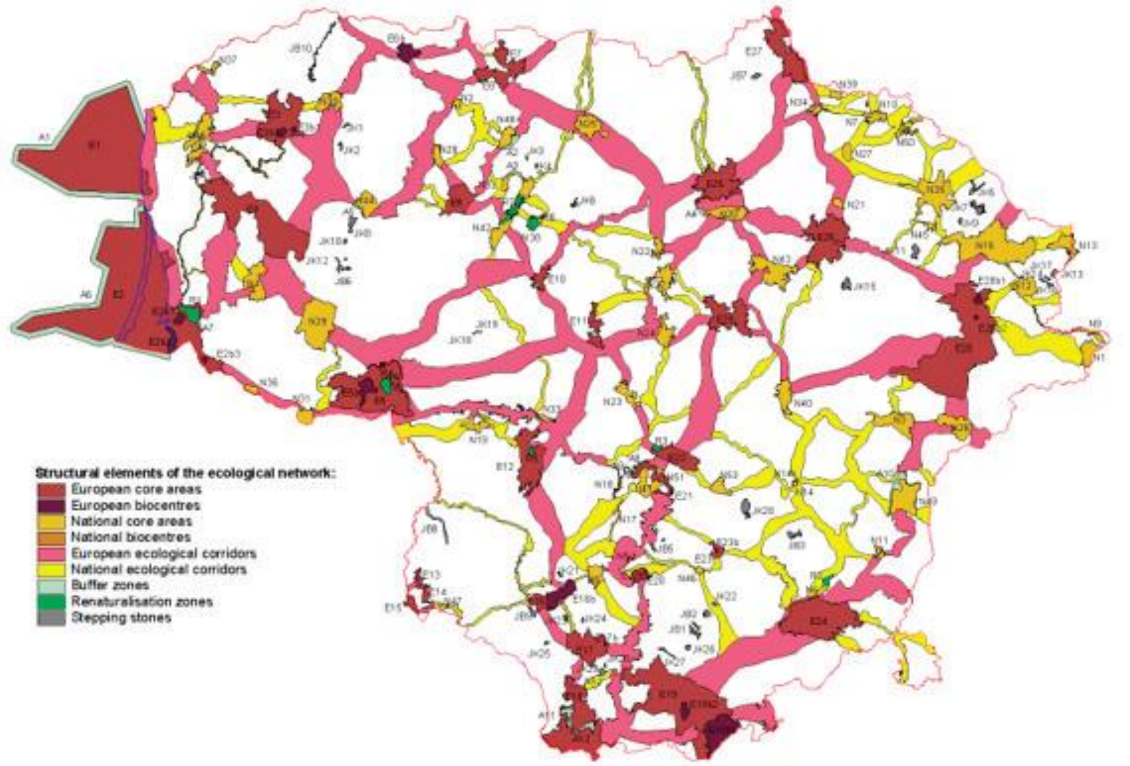


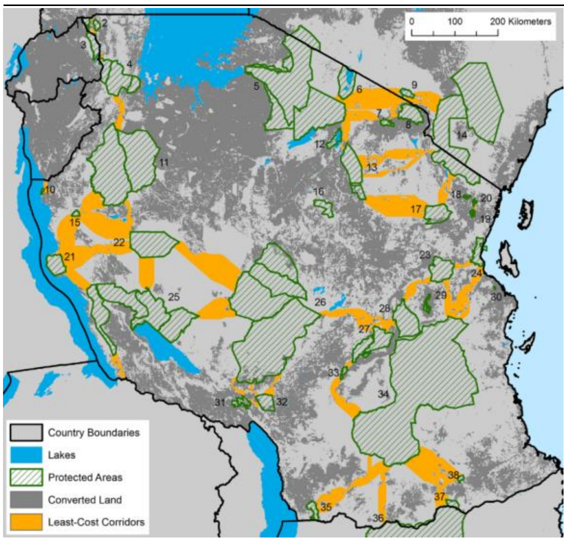
Figure 3: The Ecological Network of Lithuania

Source: Sepp and Kaasik, 2002

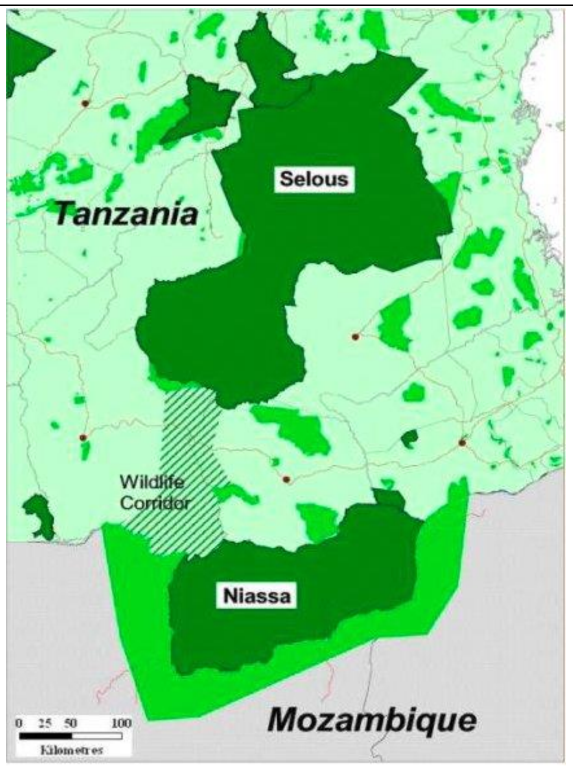
In Africa corridors have been established, mainly for wildlife conservation. These wildlife corridors target the free movement of animals between various types of protected areas. They vary in scale, from local to national and transboundary scales. Examples include a corridor linking Kibale National Park and Queen Elizabeth National Park in western Uganda, established almost 100 years ago.

In Tanzania, recently 52 potential wildlife corridors (Figure 4) linking protected areas across the country were identified and mapped using an integrated technique of GIS and interviews with local residents (Riggio and Caro, 2017).

Another example, also from Tanzania, is the Selous-Niassa wildlife corridor (Baldus et al, 2003). The trans-boundary corridor connects the Selous and Niassa game reserves (Figure 4) in Tanzania and Mozambique, linking two major elephant groups with a combined estimated population of 64,400. The corridor is 30-40km wide and 200 km long. Agreements reached with local communities not to expand farmland beyond a set boundary combined with law enforcement to combat trans-border poaching were crucial for the success of the corridor (Baldus et al, 2003; Eakin, 2017).



Proposed network of wildlife corridors in Tanzania



Selous-Niassa wildlife corridor

Figure 4: Wildlife corridors in Tanzania

Source: Riggio and Caro, 2017; Tanzanian Wildlife Research Institute, 2009

In Ethiopia, so far there is no experience of establishing and using corridors in conservation. However, a number of discussions and efforts are ongoing to establish corridors for conservation. For instance, Ethiopia submitted a proposal to create and manage corridors for White Eared Kob (*Kobus kob leucotis*) to secure international cooperation for its conservation (CMS, 2014).

White Eared Kob are known for their annual migration between Gambella National Park and wetlands of South Sudan. The migration is described as Africa's second largest terrestrial wildlife migration, second only to the Serengeti's migration of wildebeest, and is one of the natural world's great spectacles. However, their habitat is under growing pressure mainly due to political instability with refugee settlements along the migration route and subsequent degradation. The proposal has not resulted in practical action.

The Biodiversity and Forestry Program (BFP) of the GIZ has studied and mapped the elephant migration route between Chebera Churchura National Park and the Kaffa Biosphere reserve and proposed a corridor establishment (Bauer et al. 2016).

Corridor establishment has also been discussed in connection to Church Forest Conservation in northern Ethiopia. Church forests in this part of Ethiopia represent precious remnants of native forests. However, these remnants are disconnected connectivity (Wassie et al., 2010).

Discussions on corridor establishment are ongoing, including a recent workshop organized jointly by Munich Technical University, Ethiopian Environment and Forest Research Institute (EEFRI), EFCCC and Organization for Rehabilitation and Development in Amhara (ORDA), but have yet to result in concrete action.

The current work by RLLP/SLMP is perhaps the pioneer in pushing towards a practical application of Green Corridors in the country. The corridors to be established by the RLLP/SLMP will contribute not just to biodiversity conservation, but also to forest landscape restoration (FLR), and sustainable socio-economic development.

Lessons learnt

The lessons learnt compiled by the studies mentioned above are:

- Corridors are effective for biodiversity conservation. To maintain or establish linkages between viable habitats is more cost effective, and often the only feasible option for conservation in comparison to e.g. increasing the size of protected areas.
- Ideally, corridors are established while (large remnant patches of) habitat still exist / before the habitat becomes very fragmented. It is more cost-effective to protect existing habitats than to restore degraded landscapes.
- Corridor design should be based on needs for habitats and of species related to the threats to which they are exposed. A flexible design, involving a combination of different approaches and different mechanisms is often best.
- The planning and implementation of corridors requires capacity building. Related experiences of stakeholders on the ground are very limited, i.e. stakeholders will require new skills for planning and implementation of corridors.
- Corridors require a cross-sectoral approach and involvement of different stakeholders (government, NGOs, CBO, private sector, people impacted by corridors) and from different levels (national to local). The buy-in of government and local communities is essential for successful implementation and maintenance of corridors.
- Corridors require careful planning and long-term commitment. With usually many stakeholders involved, it takes time and patience to fully implement them. It helps to start implementation of ecological networks with (smaller) priority projects and activities to build support and capacity. Large-scale and longer-term conservation and socio-economic needs can be addressed later.
- Corridors (and corridors) are best planned and implemented in combination with/as components of land use plans. The need for different levels of protection and intensity of use (i.e. core, buffer, corridor and sustainable use zones) can be reflected best in land use plans.
- Corridors must be a component of community development, addressing livelihood needs and poverty alleviation through the application of participatory processes. Corridors usually are compatible with a wide variety of human uses and therefore, can be part of sustainable development.

2.2.3 Recommendations for the selection and design of Green Corridors

Based on the above cited literature, recommendations for the prioritization of corridors and design features could be compiled, and are listed below.

Prioritization of corridors

For the prioritization of corridors Bennett (2003, p. 169) suggested the following criteria, giving preference to corridors that:

- Maintain natural ecological processes and the continuity of species distributions at the bio-geographic and regional level;
- Connect/protect unique and essentially irreplaceable habitats;
- Benefit species of threatened conservation status;
- Include broad continuous tracts of natural undisturbed vegetation;
- Provide continuity for entire assemblages of species; and
- Provide multiple environmental and social benefits without compromising the corridor's value for fauna conservation.

Corridor design features

Corridor design ultimately depends on the purpose they serve. For instance, in the case of wild-life corridor, it depends on the target wildlife that uses the corridor. According to Eakin (2017), wildlife corridors "should be secure enough to encourage animals to enter […] but not be so secure that it encourages [wildlife] to stay". Nonetheless, corridors have also common features, listed in Table 4.

Table 4: Corridor design features

Feature	Details and examples
▪ Continuity	▪ Uninterrupted lines are better than stepping stones Distance between stepping stones should be short (but depends on the species)
▪ Size	▪ Wider and/or multiple parallel corridors are better than a single, narrow one Wider corridors can contain different protection/use zones, similar to protected areas
▪ Habitat	▪ Building on existing remnants of habitat (e.g. church forest) ▪ Containing diverse natural and man-made structures and vegetation for shelter and food, e.g.: – Rivers/streams and riverine vegetation – Ridgelines – Vegetation along roads and fences – Hedges, windbreaks, woodlots ▪ Restoration preferably with native plant species

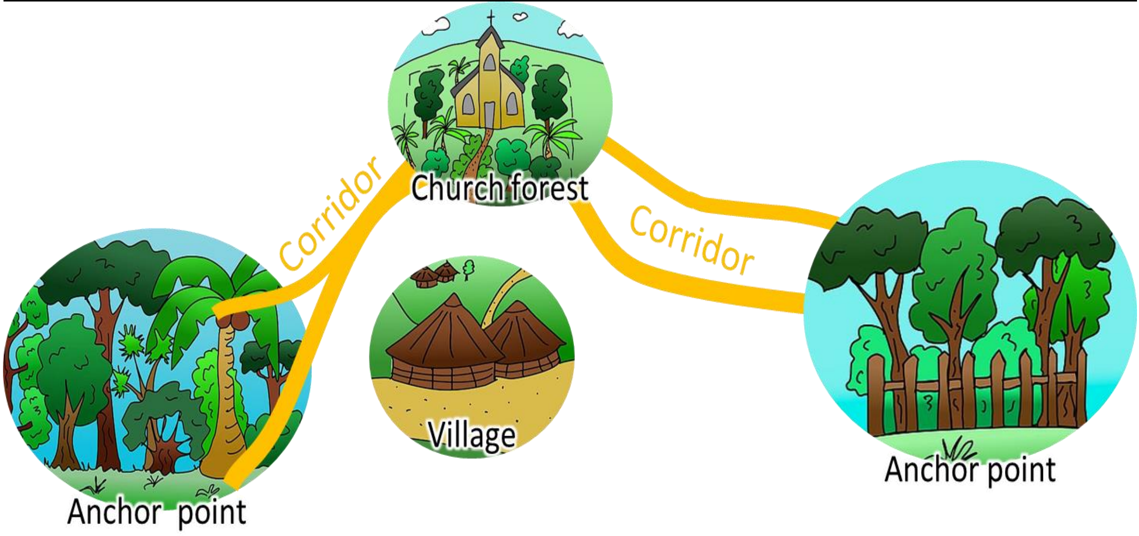
3 GUIDING PRINCIPLES FOR GREEN CORRIDOR SELECTION

The ToR and RLLP project appraisal document (WB, 2018) provide an initial framework for the selection and design of Green Corridors. GCs:

- Should link areas of significant biodiversity (anchor points) with each other or with SLMP micro-watersheds,
- Must be within the watersheds included in the SLMP I, II, and the RLLP,
- Should have multiple functions, i.e. contribute to biodiversity conservation AND other ecosystem services, and
- Should be linear or non-linear structures of up to an average 10km length and with variable width depending on the situation.[8]

The design of GC requires consideration of two components:

1. Core habitats or biodiversity hotspots (called anchor points) that are to be connected by corridors, and
2. The corridors that connect these anchor points.



Note: buffer areas may be needed for both in actual design depending on the landscape and willingness of land owners

Figure 5: Example of anchor points and green corridors

[8] The RLLP includes resources for 10,000ha or 20 Green Corridors. Assuming average width of 500m, 200km of corridor should be established.

3.1 Requirements for anchor points

The starting point in the designing of a GC is to define what can constitute core biodiversity habitats (anchor points) in the target landscape. Identifying and defining anchor points is not an easy task by itself, and anchor points need to be selected carefully.

Ecosystems that are good candidates as anchor points include:

- Formally protected areas or Biosphere Reserves;
- Larger areas of remnant natural forest, wetlands, and woodlands. Plantations do not qualify.

Other criteria are:

- Size of anchor points: Target size can vary between landscapes and/or may be determined to some extent by how hotspots are detected.[9]
- Ecosystem quality: The level of degradation determines the suitability of an area as anchor point. More degraded sites may not qualify as anchor point but could be part of the GC.

In a given landscape (e.g. watershed) many candidate anchor habitats may co-exist and it may not be practical and economic to connect all of them. In most cases, stakeholders[10] will need to prioritize or select only the most promising hotspots using quantitative and qualitative criteria.

Two categories of criteria are suggested for the selection and prioritization of anchor points.

1. **Characteristics of anchor points:**
   - Ecosystem quality
   - Ecosystem size
   - Ecosystem location
2. **Conditions for connectivity:**
   - Distance between anchor points
   - Barriers between anchor points
   - Existing desirable landscape features in-between anchor points

3.1.1 Characteristics of anchor points

- **Ecosystem quality**

  Habitat quality refers to the likely diversity of flora and fauna in given area. The current conservation status (PA, BR) is used as a proxy indicator for intactness of the habitat. For areas outside PAs, the type of ecosystem/vegetation is used.

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[9] For example, for very large landscapes (as in the RLLP) GIS analysis will be required. Anchor points need to have a minimum size to be reliably detectable. For smaller areas, e.g. within a specific watershed, anchor points could be identified by e.g. stakeholders and experts, i.e. can also be quite small.

[10] Stakeholders in this context are persons, communities, community groups (CBOs) and/or other institutions/organizations that have direct or indirect interest or stake and concern in the establishment and management of GC in their locality, The primary stakeholders here are farm households, community group and institutions that allocate either private or communal lands for the establishment of the GC and also potentially affected by wild animals that will use the corridors.

Where available, information regarding the level of disturbance or degradation can be added (based e.g. on species richness, presence of flagship or endemic species).

- **Habitat size**

  The size of a habitat or ecosystem is an important factor for the long-term survival of many species. Larger ecosystems are usually more divers and more likely to provide the full spectrum of ecosystem functions and services. They are more likely to contain a large number of species and number of individuals within one species, have less edge effects (human disturbance), and can withstand or absorb adverse circumstances (humans, but also climate change) better than smaller areas. While there may be exceptions to this rule, size can be assessed relatively easily, making it a suitable criterion for the selection of anchor points.

- **Location**

  The location of the anchor point is important. It influences the importance of the anchor habitat for ecosystem services other than biodiversity, e.g. protection of water sources. Potential anchor points located on hilltops and hillsides, or along river banks have additional values.

Table 5: Ranking of anchor points according to ecosystem quality, size, and location

Criteria	Weight	Options	Score
Ecosystem quality	40%	Ecosystem designated as PA or BR	40
		No PA status, (primary) natural forest	30
		All other natural ecosystems (wetlands, woodlands, grasslands), Area Exclosures and PFM*	20
Ecosystem size	40%	Large	40
		Medium	20
		Small	10
Ecosystem location	20%	Located on hill tops, hill sides, along river banks or lake shores	20
		Those located else where	10
Total	**100%**		**Max: 100** **Min: 40**

*If area exclosure and PFM boundaries are known.

3.1.2 Conditions for connectivity

Features of the landscape between the anchors determine the potential to establish a corridor. As a result, even landscapes containing highly suitable anchor points may have to be discarded if the potential to connect the anchor points is very low. Vice versa, anchor points of a lower suitability may be given preference because of the conducive landscape in-between.

- **Distance between anchor points**

  Anchor points located within a short distance from each other are more likely to become (or remain) connected than those farther apart. Additionally, the cost of corridor establishment is likely to by higher the longer the distance between the anchor points.

- **Barriers**

Man-made structures and certain land uses can make the establishment of corridors difficult or prevent it altogether. Depending on their type and size of barriers, GCs can bypass them. In other cases, barriers may be too big to cross or go around. Landscapes with major barriers must be excluded from the list of potential corridors (Table 6)

- **Desirable features**

  Some landscapes may contain elements which facilitate the establishment of GCs. Where such elements exist, they can be incorporated into the GC; and cost and effort of GC establishment is likely to be lower.

Table 6: Ranking of anchor points according to the conditions for connectivity

Criteria	Weight	Options	Score
Distance	40%	< 5km distance between the candidate anchor habitats	40
		5-10km distance between the candidate anchor habitats	20
		> 10km distance between the candidate anchor habitats	0
Barriers	40%	No barriers	40
		Minor structures, e.g. individual houses, small villages, or minor roads	20
		Major structures, e.g. towns, railways & major roads, industrial areas, or commercial scale agriculture*	**GC rejected**
Desirable features	20%	Stepping stones or linear features exist: Forest patches, church forests, extensively used land (e.g. rangeland), riverine forests, larger rivers or streams, existing soil-water conservation features (e.g. terraces, hedges)	20
		None of the above	0
Total	**100%**		**Max: 100** **Min: 20**

* The presence of major structures prevents GC establishment, or would make it very difficult or costly. Hence, corridors having to pass major barriers will be rejected. Barrier assessment should take into account developments (e.g. a town expected to grow into the direction of the corridor, road scheduled to be upgraded, or planned industrial development)

3.2 Prioritizing and selecting landscapes for Green Corridors

The prioritization or selection of landscapes for GC development follows a two-step process, applying the criteria listed above.

Step 1: Evaluate the anchor point characteristics

Step 2: Evaluate the conditions for connectivity

Useful sources of information are:

- Maps showing the boundaries of protected areas, PFM, and exclosures
- Land cover/land use maps
- Topographic maps or digital elevation models

- Qualitative information for PAs or other natural ecosystems (species diversity and abundance, presence of endemic or flagship species, degradation of the ecosystem), and
- Maps showing existing and planned settlements, infrastructure, and industrial developments.

For smaller projects or landscapes the evaluation can be done manually. Large projects covering large or multiple landscape requires analysis of the information using a geo-spatial information system (GIS).

After evaluation of the individual criteria, the total score can be calculated for the anchor point characteristics and conditions for connectivity respectively, using the tables above. The options with the highest combined score should be prioritized as illustrated in Figure 6. Options with a zero score for conditions: barriers (Table 6) will be excluded.

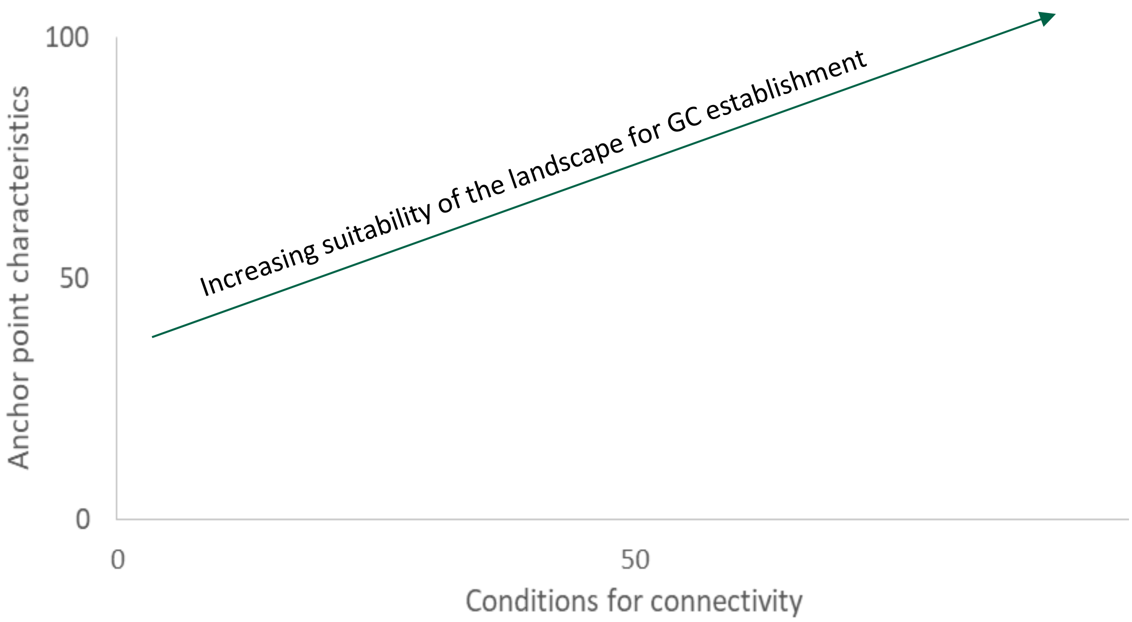

Figure 6: Prioritizing and selecting landscapes for green corridors

4 PROPOSED GREEN CORRIDORS

For the SLMP/RLLP watersheds anchor points and potential corridors connecting them were identified applying the principles described above. To cover the six regions efficiently, the initial steps of the process were automated using geo-spatial analysis, followed by manual refinement of the corridor routes identified by the GIS. The analysis was conducted in five steps:

1. Compilation of spatial information
   - Land cover / use
   - Protected areas
   - Infrastructure
   - Terrain (digital elevation model)
   - Settlements, industrial developments and large scale agriculture
2. Stratification into high/low forest cover areas

   The SLMP watersheds in the six regional states were classified into two strata according to general forest cover/existence of large continuous forested areas relying on expert opinion (see Figure 7). Most of the watersheds are in the low forest cover area (stratum 1). Parts of Gambella, Oromia, and SNNP are classified as high forest cover area (stratum2).

   The minimum size of the anchor points was set to 5 and 100 hectares for low and high forest cover areas respectively. To avoid unjustified exclusion of watersheds with small forest area located in stratum 2, the algorithm was applied with the 5ha threshold for watersheds without hotspot detected in first iteration.
3. Identification of anchor points and possible corridor routes

   Hotspots, their suitability as anchor points, and potential corridor routes were identified using an algorithm comprising the criteria described in chapter 3.

   The minimum condition for a GC is the presence of two anchor points detectable with GIS within a project watershed. With very few exceptions, all watersheds had two or more hotspots.

   The algorithm proposed possible corridor routes with favorable connectivity conditions between the most suitable anchor points. Each corridor identified by the algorithm (including the respective anchor points) received a suitability factor. An example calculation is provided in Annex 3. Accordingly, over 200 corridors were identified.
4. Compilation of the Green Corridor long list

   Of the corridors identified in step 3, 64 corridor routes were selected for future implementation. The number of corridors per regional state is proportionate to the number of SLMP woredas in the state.
5. Manual revision and refinement of the corridor routes

   Applying GIS to identify corridor routes has limitations – largely owing to the quality and resolution of the spatial data sets available. For example, the land cover / use classification is not 100% correct, smaller terrain features cannot be recognized using digital elevation models, and infrastructure, commercial developments, and settlements may be mapped incorrectly.

Hence, each of the proposed corridor routes was visually verified using satellite imagery. Where necessary, the route was adjusted applying once more the criteria listed in chapter 3.

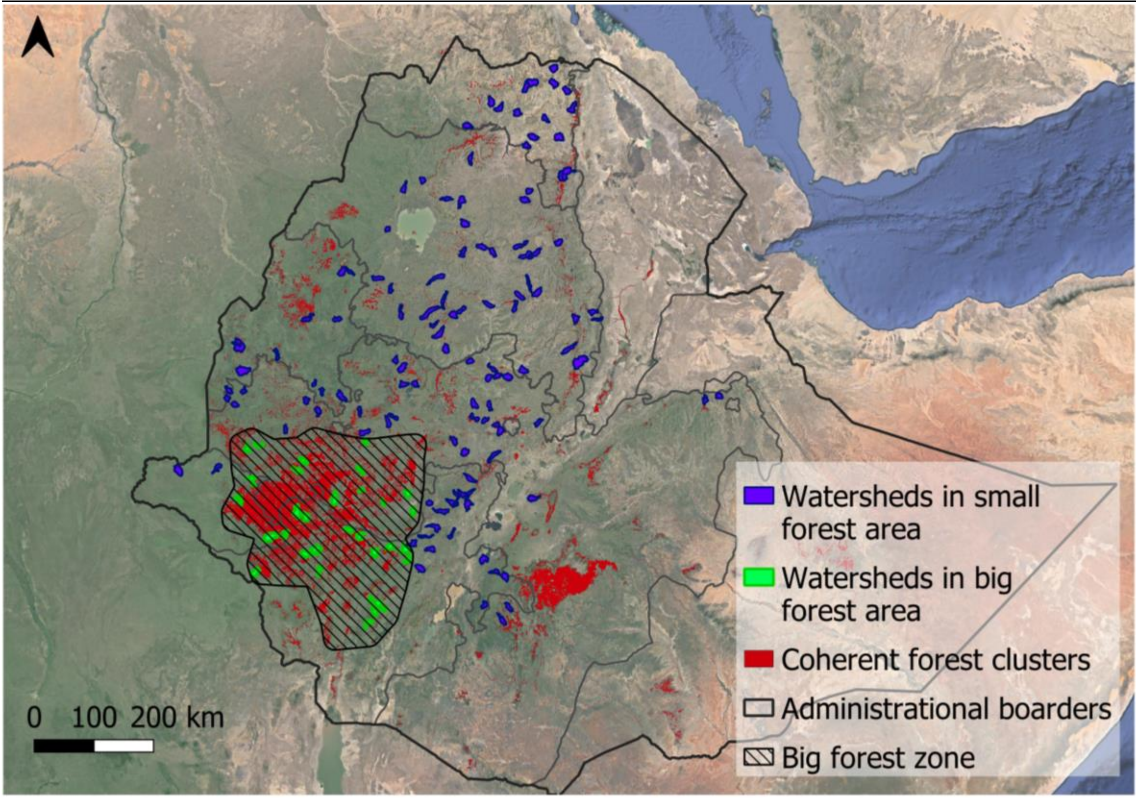

Figure 7: Stratification of the SLMP/RLLP sites by forest cover

The **results** of the corridor identification are presented in Table 7.

- The suitability score indicates the potential to establish a Green Corridor. Lower values indicate higher potential.
- The GC length is the shortest possible connection between the selected anchor points, while avoiding barriers or land use/cover less suitable for corridor establishment. The potential routes vary in length, ranging from 2 to over 100km. Longer corridor routes often encompass several hotspots (which could be anchor points), i.e. can be shortened to match the resources available.
- The corridor area is the area that would be covered by the GC if it were 500m wide along its entire length. The actual Green Corridor width (and area) may be less or more depending on the environmental and socio-economic conditions encountered in the Green Corridor planning process. The final Green Corridor will have variable width, wider in places where conditions are favorable and narrower where not. (For details refer to the draft guideline "Green Corridors: Design, Selection and Development".)
- Land cover/use statistics provide an indication of the effort that may be required to establish the Green Corridor. For example, forest, woodland, shrubland & afro-alpine vegetation likely require relatively low-cost measures like area enclosure. On the other hand, interventions on crop land are more sensitive due to the economic implications of required adjustments of land management and use may have.

Table 7: List of potential Green Corridors

Region	Zone*	Woreda*	Major Watershed*	Suitability score⁺	Corridor length (km)	Corridor area (ha)	Land cover/use: Forest, woodland, shrubland & afro-alpine	Crop land & grass land	Bare land	Wetland & water	Settle-ment
Amhara	Awi	Dangila	Awisi	93	35	1661	37%	62%	1%	0%	0%
	Awi	Fagita Lekoma	Upper Guder	95	49	2387	34%	65%	2%	0%	0%
	Central Gonder	Lay Armachiho	Mahina	106	8	422	37%	55%	6%	0%	2%
	East Gojjam	Bibugn	Arefa	93	55	2832	37%	47%	16%	0%	0%
	East Gojjam	Gozamin	Dijil	104	55	2760	24%	73%	3%	0%	0%
	East Gojjam	Machakel	Ketech	83	26	1181	38%	55%	6%	0%	0%
	North Gondar	Jan Amora	Tilk Wonz	100	59	2946	27%	57%	14%	1%	0%
	North Gondar	Merab Belesa	Kabtiya	97	15	801	49%	29%	21%	0%	0%
	North Shewa	Kewet	Robi	85	114	5797	55%	40%	6%	0%	0%
	North Wollo	Guba Lafto	Tikur Wuha	70	53	2596	56%	40%	2%	1%	1%
	North Wollo	Meket	Tilkit Deremo	92	63	3218	31%	49%	20%	0%	0%
	Oromiya	Dewe Harewa	Dinkiye	110	24	1257	42%	38%	20%	0%	0%
	South Gonder	Ebinat	Rib Ebnat	92	39	2005	53%	26%	21%	0%	0%
	South Gonder	Misrak Este	Chena Gomit	96	35	1812	37%	58%	4%	1%	0%
	Wag Himra	Gazgibila	Bela Amba	93	38	1973	64%	20%	16%	0%	0%
	Wag Himra	Sekota	Diba	94	17	859	51%	22%	26%	0%	0%
	West Gojjam	Dembecha	Kechem	88	105	5284	45%	48%	7%	0%	0%
Benishagngul Gumuz	Assosa	Oda Bildagul	Buchi	100	49	2372	47%	53%	0%	0%	0%
	Maokomo Special	Maokomo	Upper Yabus	101	32	1592	65%	34%	1%	0%	0%
	Metekel	Pawe	Alpapawa	95	48	2374	59%	41%	0%	0%	0%
	Metekel	Wenbera	Alelitu	91	45	2226	51%	48%	1%	0%	0%

Table 7: List of potential Green Corridors

Region	Zone*	Woreda*	Major Watershed*	Suitability score[+]	Corridor length (km)	Corridor area (ha)	Land cover/use				
							Forest, woodland, shrubland & afro-alpine	Crop land & grass land	Bare land	Wetland & water	Settle-ment
Gambella	*Agnuwak*	*Abobo*	*Dimbong*	88	25	1287	89%	10%	0%	0%	0%
	Mejenger	*Godere*	*Zeiy* [x]	61	27	1418	91%	9%	0%	0%	0%
	Nuwer	Jikawo	Adura	75	10	554	83%	17%	0%	0%	0%
Oromia	Arsi	Tiyo	Ilu	99	61	3066	35%	63%	1%	0%	0%
	East Wellega	Leqa Dulecha	Nagesso	108	39	2002	25%	74%	1%	0%	0%
	East Wellega	Sasiga	Haya	84	37	1931	57%	43%	0%	0%	0%
	Guji	AnaSora	Ababa	94	53	2610	38%	62%	0%	0%	0%
	Horo Gudru Wellega	Amuru	Dero_Welege	99	40	2048	53%	46%	0%	0%	0%
	Horo Gudru Wellega	Jardaga Jarte	Chogo	102	54	2764	50%	49%	1%	0%	0%
	Ilu Aba Bora	*Gechi*	*Gechi*	82	37	1915	58%	42%	0%	0%	0%
	Ilu Aba Bora	*Metu*	*Metu*	88	38	1946	49%	51%	0%	0%	0%
	Jimma	*Mana*	*Guye*	77	20	1034	65%	35%	0%	0%	0%
	Jimma	*Tiro Afeta*	*Nedhi*	92	22	1162	32%	68%	0%	0%	0%
	North Shewa	Kuyu	Chirecha	102	39	1995	30%	68%	2%	0%	0%
	North Shewa	Were Jarso	Lege Danse	95	34	1750	74%	25%	1%	0%	0%
	Qeleme Wellega	Laloqile	Lalokile	94	34	1750	38%	62%	0%	0%	0%
	Qeleme Wellega	*Seyo*	*Seyo*	113	11	585	24%	76%	0%	0%	0%
	West Shewa	Dendi	Dendi	105	29	1425	17%	80%	2%	0%	0%
	West Wellega	Boji Dermeji	Boji	97	38	1947	36%	64%	0%	0%	0%
	West Wellega	Gimbi	Gefere	82	53	2692	55%	45%	0%	0%	0%

Table 7: List of potential Green Corridors

Region	Zone*	Woreda*	Major Watershed*	Suitability score+	Corridor length (km)	Corridor area (ha)	Land cover/use: Forest, woodland, shrubland & afro-alpine	Crop land & grass land	Bare land	Wetland & water	Settle-ment
Southern Nations, Nationalities and Peoples	*Bench Maji*	*Meant Goldiya*	*Aday Abeba*	88	28	1451	47%	53%	0%	0%	0%
	Bench Maji	*Semen Bench*	*Gacheh*	75	43	2213	68%	32%	0%	0%	0%
	Dawuro	Genna	Bachire	101	40	2075	55%	40%	5%	0%	0%
	Dawuro	*Mareka*	*Mansa*	79	54	2752	64%	36%	0%	0%	0%
	Dawuro	*Tercha Zuriya*	*Dibissa*	65	52	2637	84%	16%	0%	0%	0%
	Gamo Gofa	*Geze Gofa*	*Mito*	99	24	1178	30%	70%	0%	0%	0%
	Kefa	*Chena*	*Chitachuka*	82	53	2665	59%	41%	0%	0%	0%
	Kefa	*Gesha*	*Yoga*	70	62	3208	71%	29%	0%	0%	0%
	Kefa	*Gimbo*	*Geshi*	90	24	1220	35%	65%	0%	0%	0%
	Kefa	*Menjwo*	*Gondero*	73	36	1882	72%	28%	0%	0%	0%
	Kefa	*Menjwo*	*Gondero*	76	4	249	65%	35%	0%	0%	0%
Tigray	Central Tigray	Kola Temben	Selam	103	2	131	72%	28%	0%	0%	0%
	Central Tigray	Kola Temben	Selam	91	32	1652	88%	10%	2%	0%	0%
	Central Tigray	Nader Adet	Ruba Adiet	97	40	1984	65%	20%	15%	0%	0%
	Eastern Tigray	Atsbi Wonberta	Womberta	89	54	2738	67%	28%	5%	0%	0%
	Eastern Tigray	Ganta Afeshum	Suluh	78	28	1440	59%	24%	17%	0%	0%
	Eastern Tigray	Ganta Afeshum	Suluh	89	13	676	53%	28%	19%	0%	0%
	Eastern Tigray	Gulo Mekeda	Kortoto	107	35	1819	52%	24%	24%	0%	0%
	Eastern Tigray	Saesie_Tsaeda_Emba	Abene-A	90	24	1233	55%	32%	13%	0%	0%
	North Western Tigray	Medebay Zana	Adi Tsegora	102	29	1481	68%	23%	9%	0%	0%
	North Western Tigray	Tselemti	Buya	108	26	1355	44%	27%	29%	0%	0%

Table 7: List of potential Green Corridors

Region	Zone*	Woreda*	Major Watershed*	Suitability score+	Corridor length (km)	Corridor area (ha)	Land cover/use: Forest, woodland, shrubland & afro-alpine	Crop land & grass land	Bare land	Wetland & water	Settle-ment
	South Tigray	Raya Azebo	Lower Burka Abagabir	70	35	1831	85%	7%	8%	0%	0%
	South Tigray	Raya Azebo	Lower Burka Abagabir	60	3	169	91%	0%	9%	0%	0%

*Watersheds falling within the area of high forest cover are marked with italic letters.

+Corridor routes with lower values are more suitable for Green Corridor development than routes with higher values. Refer to Annex 3 for details.

xThe corridor in Godere woreda (Gambella) was identified manually after feedback from the project. The six project watersheds in Gambella have very high forest/woodland forest cover, limiting the ability to identify concrete anchor points and corridor routes using GIS.

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ANNEX

Annex 1: Conservation areas in Ethiopia

Protected area categories in Ethiopia

Type	Number	Area (km²)	Remarks
National Parks	21	44,600	▪ Areas targeting the protection and sustainable management of wildlife and their habitats. ▪ The level of formality is highest in NPs and lowest in Community Conservation Areas. The actual success of protection is strongly linked to community participation, i.e. may be higher in Community Conservation Areas. ▪ The PAs can be under the management of federal or regional government.
Wildlife Sanctuaries	3	7,000	
Wildlife Reserves	11	24,800	
Controlled Hunting Areas	18	13,200	
Open Hunting Areas	7	7,00	
Community Conservation Areas	8	1,900	
Total	**68**	**91,500**	

Other conservation areas in Ethiopia

Type	Number	Area (km²)	Remarks
National Forest Priority Areas	58	48,000	▪ FPAs are remnant natural forests of high biodiversity conservation value. They were identified in the 1980s but remained nominal with no management and policy actions following their designation.
UNESCO Biosphere reserves	5	15,700	▪ International category not reflected in the Ethiopian legislation. ▪ 4 BRs focusing on forest coffee, forest and 1 on lake ecosystems ▪ Overlap with Forest Priority Areas.
Participatory Forest Management Areas	All regions except Afar and Somali	15,000	▪ Partially overlap with Forest Priority Areas. ▪ Local communities in the vicinity of forests are mobilized and engaged along-side government to manage forests. ▪ Reduces open access and the related degradation.
Total		**78,700**	

Source*: Compiled from different sources; Area values presented are rounded (e.g. FDRE, 2005; Getahun 2017; Firew and Solomon, 2018; Alemneh, 2015; Young, 2012).*

Annex 2: Community participation in PA management

Article 5(2) of the regulations for wildlife development, conservation and utilization (No. 163/2008) permits access to national parks and wildlife sanctuaries for seasonal utilization of natural resource such as bee keeping, honey harvesting, cutting and taking of forage and medicinal plant collection under controlled conditions based on agreements made between a national park or wildlife sanctuary management and the surrounding communities. Article 5(3b) entitles persons who were inhabitants of the wildlife reserve areas prior to the date of its establishment to continue residing therein. Article 5(4) states that persons authorized to reside in a wildlife reserve shall have the right to cultivate their land plots without expanding, to allow their domestic animals graze and water, and undertake bee keeping therein. But when the organ administering the wildlife reserve wishes to further develop the area, the in habitants may be resettled elsewhere.

Article 3b of the regulation (No. 163/2008) further states "Persons who were inhabitants of wildlife reserve prior to the date of its establishment, to continue residing therein, and Article (4) states persons authorized to reside in a wild life reserve pursuant to sub-article 3(b) of this Article shall have the right to cultivate their land plots without expanding, to allow their domestic animals graze and water, and to undertake bee keeping therein; provided however, that if the organ administering the wildlife reserve wishes to further develop the area, the in habitants may be resettled elsewhere. Moreover, based on agreements made between national park or wild life sanctuary management and the surrounding communities, seasonal utilization of natural resource such as bee-keeping and honey harvesting, cutting and taking of forage and medicinal plant collection, may be permitted under controlled conditions (Article 2(e) (regulation No. 163/2008)."

Annex 3: Methodology for the identification of hotspots and potential corridor routes in the SLMP/RLLP watersheds

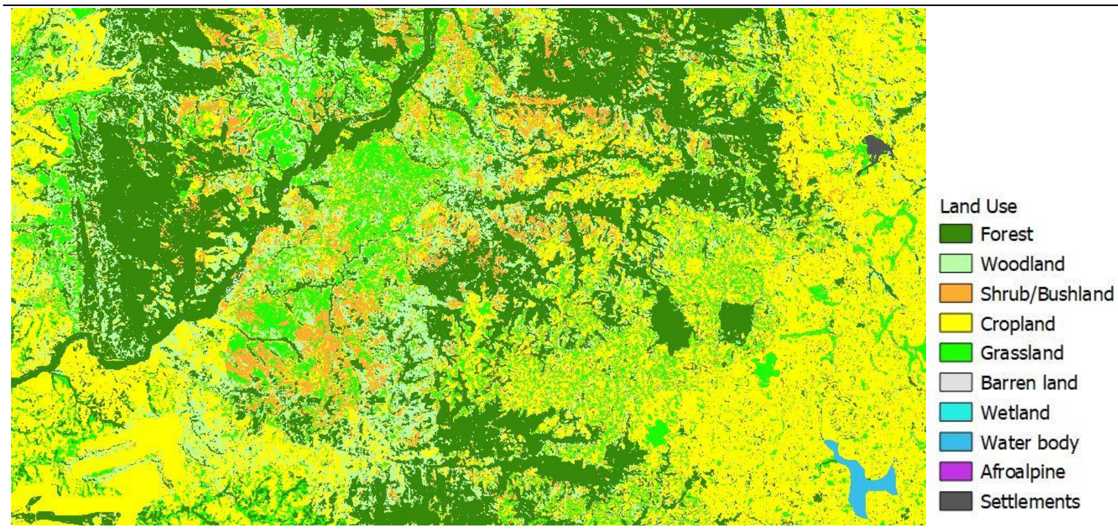
The routes for green corridors were identified using spatial information in GIS analysis. The basic idea is to first identify biodiversity hotspots that can serve as anchor points in the targeted watersheds, and second, identify routes that are likely to be effective in connecting them. GIS analysis is suited to combine the information from multiple overlapping layers at large scale. The analysis combined automated processes with manual revision and refinement to identify the most appropriate corridor pathways.

Input data

GIS layers used for anchor point and corridor identification:

- **Land cover/use**: the national dataset provided be the SLMP PCU is based on satellite data from 2016 (European Space Agency (ESA) Climate Change Initiative). It distinguishes between 10 land cover/use classes.

  The accuracy of the land cover/use classification is good for a national scale analysis. However, small-scale land use patterns are not always reflected well, due to its relatively low resolution. As a result, land use classes may not always reflect the reality.



Example for the land cover/use layer

Source: provided by the SLMP PCU, 2019

- **Protected Areas**: are gazetted and non-gazetted areas delineating areas which are protected or are worth protecting for their environmental values. A fairly comprehensive, but not complete, data set is available from the World Database of Protected Areas (WDPA, 2019). This data was merged with other data sets available from the GIZ Biodiversity and Forestry Program.

  The different protected areas often overlap each other and in many cases do not reflect the actual boundary. Nonetheless, the data set provides an indication of sites with high biodiversity values, especially in combination with the land cover/use map.

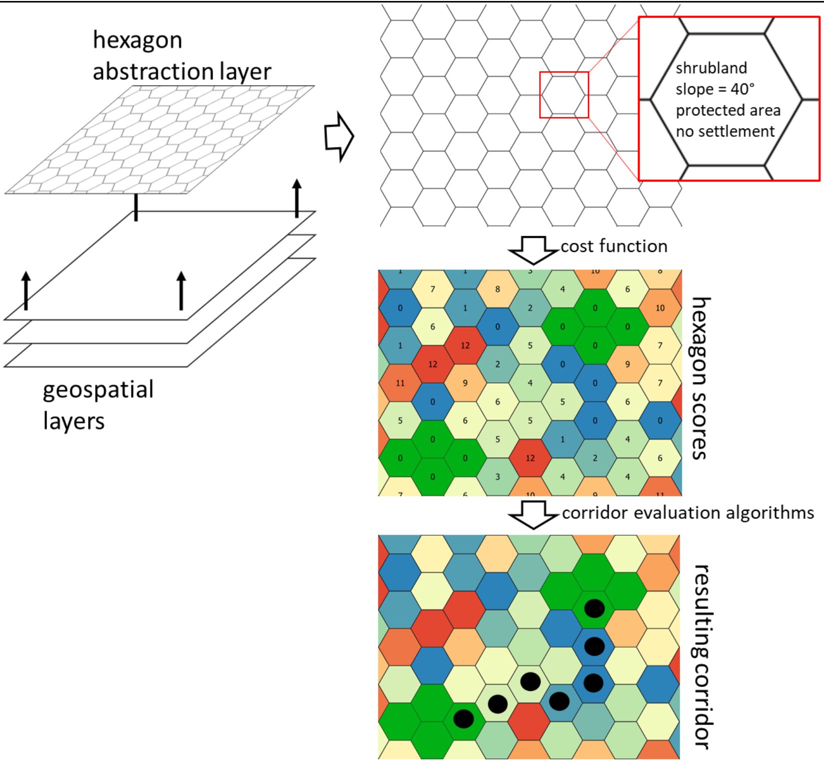
  A map of protected areas is provided in Figure 1 in chapter 2.

- **Infrastructure and industrial developments**: Open Source Map (OSM) provides different data sets showing roads and other linear infrastructure, settlements (center point and/or boundaries), as well as actual/planned developments such as industrial areas or large-scale agriculture. The OSM data is the most comprehensive geo-graphical datea set available for Ethiopia. However, OSM relies on voluntary uploads by users, i.e. is not a complete data set.
- **Administrative and watershed boundaries**: Administrative boundaries for the six regional states and boundaries for the project watersheds were provided by the SLMP PCU. The project watersheds define the boundaries of the planned green corridor interventions.
- **Digital Elevation Model (DEM)**: the model provides an indication of terrain, i.e. elevation and specific features such as slopes, mountains and hilltops, valleys and gorges and plains. The DEM raster file (SRTM30 V2, Oct. 2019) has a resolution (pixel size) of 30x30m.

  The DEM was used to identify slope classes applying the slopes classes commonly used in Ethiopia, i.e. <30°, > 30°, > 60°. The latter two slope classes were prioritized for corridor routing.

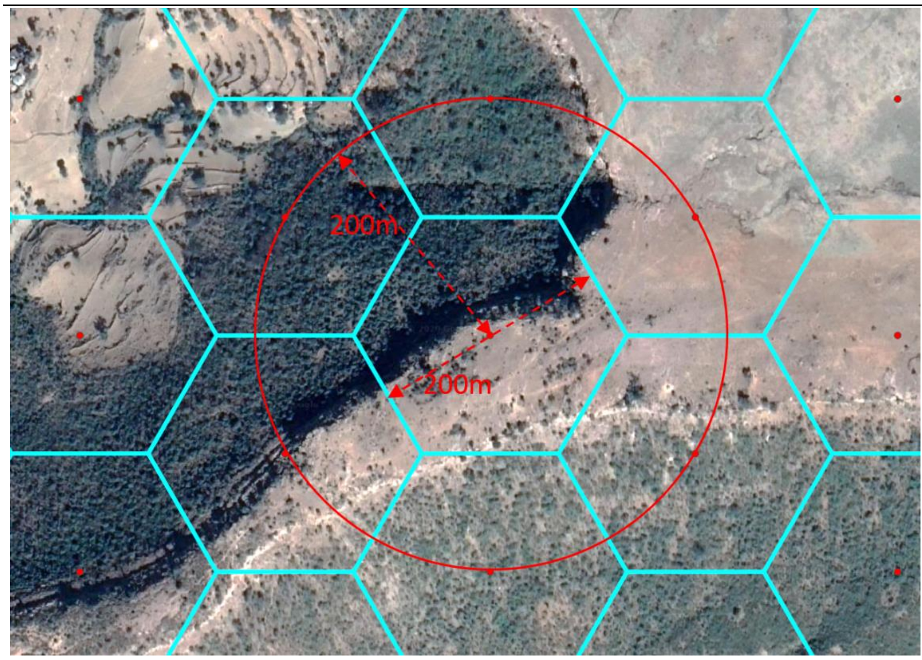
Harmonization of geo-spatial information

To apply an automated approach suited to the distribution of project intervention sites across the six regional states, the different types of spatial information listed above have to be harmonized and put into relation to each other (see figure below). A layer of interconnected hexagons was chosen to combine the different data sets. The advantage of hexagons is their direct connectivity in six directions with equal distance to all neighboring hexagons. These geometric properties are highly suitable to analyze the corridor paths.



Combining corridor criteria to a suitability score

Source: UNIQUE



Each hexagon has an area of 3.5ha.

The relatively large size of the hexagon is required to achieve a feasible level of computation time.

Hexagons used for the GIS algorithm

Source: UNIQUE

Assigning suitability score per hexagon

For each hexagon the underlying spatial information was translated into a suitability score by adding up the corresponding value for each criterion (or GIS layer). The most suitable conditions, (e.g. forest land) get very low values, while more difficult conditions (e.g. agriculture or barriers) receive higher values. That is, a hexagon with a very low value is more suitable for corridor establishment than a hexagon with a high value.[11]

The following table shows the values applied for each criterion and class.

Criteria and score per class applied in GIS analysis

Criterion	**Class**	**Suitability value**
Land cover / use The value for land cover/use assigned to a specific hexagon is based on the dominant land use within the hexagon. In this example shown in the figure above, the land use assigned would be crop or grassland.	Forest	0
	Woodland	1
	Bushland	1
	Cropland	3
	Grassland	2
	Barren land	3
	Wetland	0
	Water body	-
	Afroalpine	0
	Settlements	Barrier
Protected Area	Protected Areas	0
Infrastructure	Mayor roads	Barrier
	Railways	Barrier
Slope	Slope < 30°	4
	Slope > 30°	1
	Slope > 60°	0
Other areas	Commercial areas	Barrier
	Large scale agriculture	Barrier
	Industrial Areas	Barrier
	Residential Areas	Barrier
	Retail Areas	Barrier

Calculation example

In the following examples the corridor is shaded. The numbers within the hexagons are the suitability values per criterion based on the input parameters.

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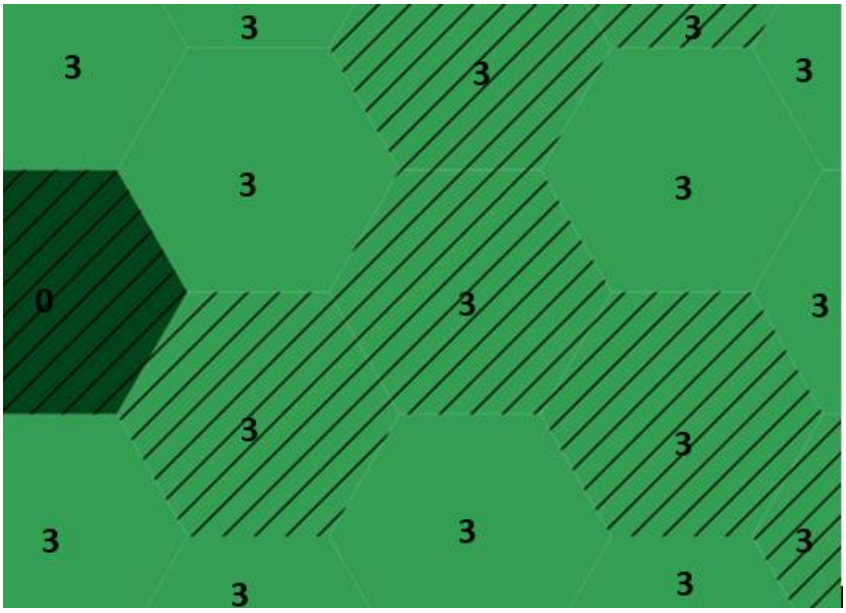
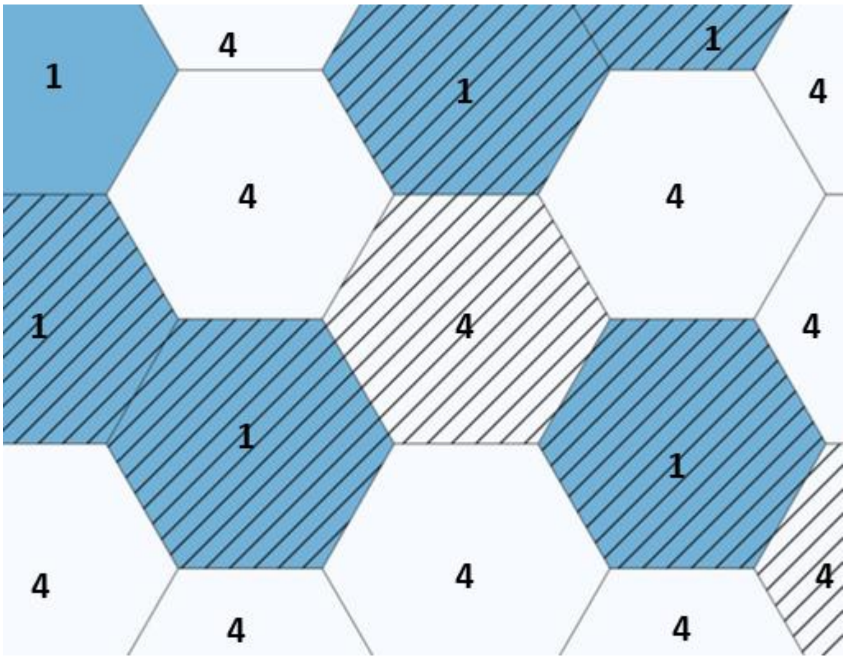
[11] *Note: the scoring applied by the algorithm in the GIS analysis is inverse to the ranking of criteria described in chapter 3, and individual values were adjusted to the available data and number of classes in each criterion. However, the principle of scoring remains the same as described in chapter 3.*



Criterion land cover/use

This layer shows only 1 hexagon of forest (value 0).

The dominant land use in the remaining hexagons is agriculture (value 3).



Criterion slope

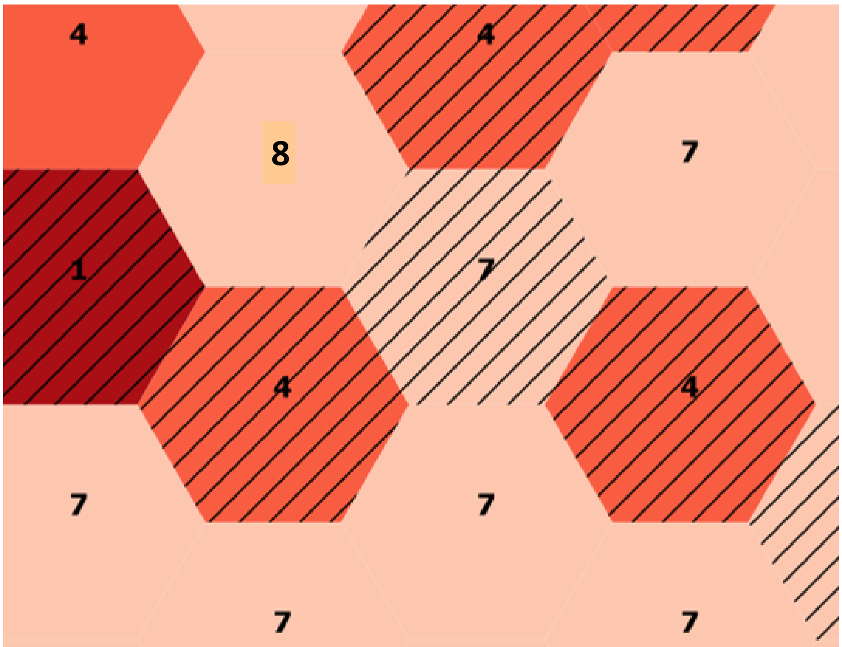
Steep and very steep slopes are a specific target for GCs, as they require protection to avoid erosion. Very steep slopes (>60°) are given very high priority.[12]

Flat terrain (<30°), while suitable for corridors is not a specific target.

The blue hexagons have a slope of >30° and therefore a value of 1 as being very suitable for a corridor.

Slopes >60° are not very common.[13]

[12] Very steep slopes often are not used / should not be used for agriculture according to the legislation.
[13] Respectively could not be identified with the relatively coarse resolution of the digital elevation model. Only long, continuous slopes can be recognized.



Criterion barriers

Where barriers exist, the value of the hexagon is set to a maximum of 8 (barrier/larger obstacle). Corridor routes selected by GIS will bypass such areas.

Suitability function for hexagons:

$$Suitability_{hexagon} = \sum value_{land\ use} + value_{slope}$$

If the hexagon contains a major barrier:

$$Suitability_{hexagon} = 8\ (not\ suitable)$$

Suitability value range for hexagons:

0	1	2	3	4	5	6	7	8
Very suitable			…		suitable		…	Not suitable

Identification of hotspots

Hotspot identification and ranking combines three criteria:

- Land cover/use: forest, wetland, afro-alpine vegetation are potentially suitable hotspots.
- Size: setting a threshold for minimum size and giving preferences to larger continuous areas of forest, wetland, afro-alpine vegetation. The threshold was set based on general forest cover in the area (see also chapter 4, Figure 7).
- Protection status: forest, wetland, afro-alpine vegetation classified as a protected area will be given preference over areas without protection status.

The following table shows the applied threshold for the two forest cover strata.

Size threshold for biodiversity hotspots

Forest cover stratum	Threshold for hotspots
High forest cover	100 ha
Low forest cover	5 ha

Finding the most suitable corridor between two or more hotspots

The criteria listed in the table above were combined in a GIS algorithm to automatize the search for suitable corridor routes.

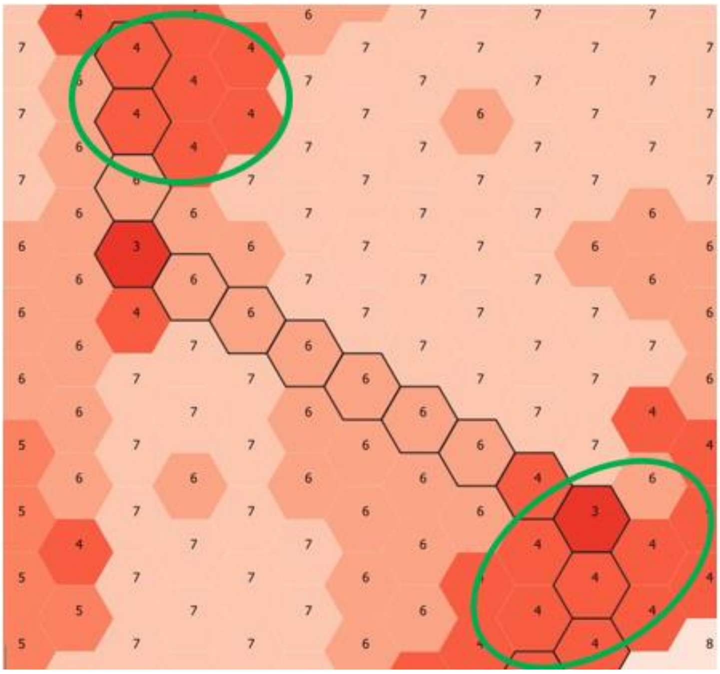
This algorithm is a function to find and connecting anchor points with the least possible effort. The algorithm explores all possible paths. The output is the path with the lowest (most favorable) total suitability score across all hexagons along its way (see Figure 10).

Put simply, the algorithm starts with the most direct path between anchor points, but deviates from the direct path if a neighboring hexagon with a better suitability score is available, then continues to the next one until reaching the second anchor point.

The total suitability score of a corridor route is calculated as the sum of all hexagons divided by the total length of the corridor (in km) thereby allowing the comparison of corridors of different length.

$$Suitability_{corridor\ route} = \frac{\sum_{i=1}^{n} hexagon_i}{length}$$

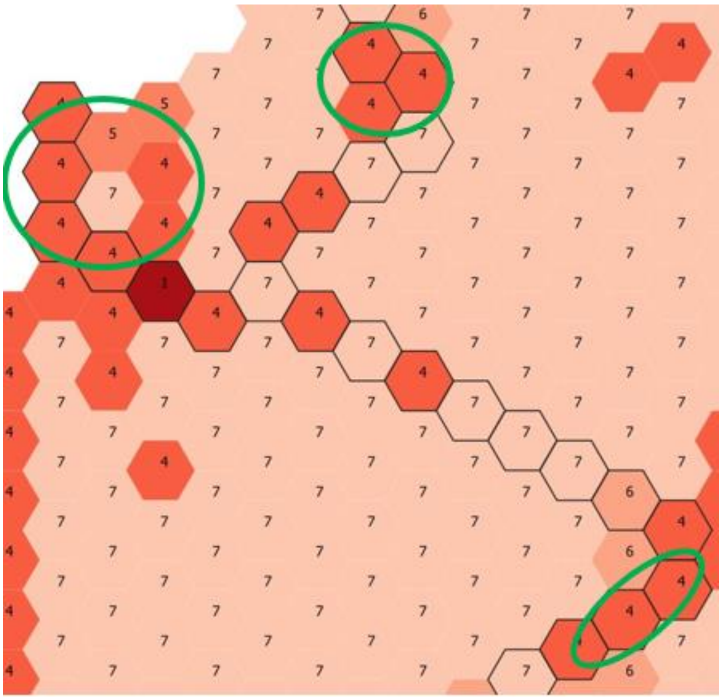
Examples for corridor routes



Connection of two hotspots with difficult connectivity

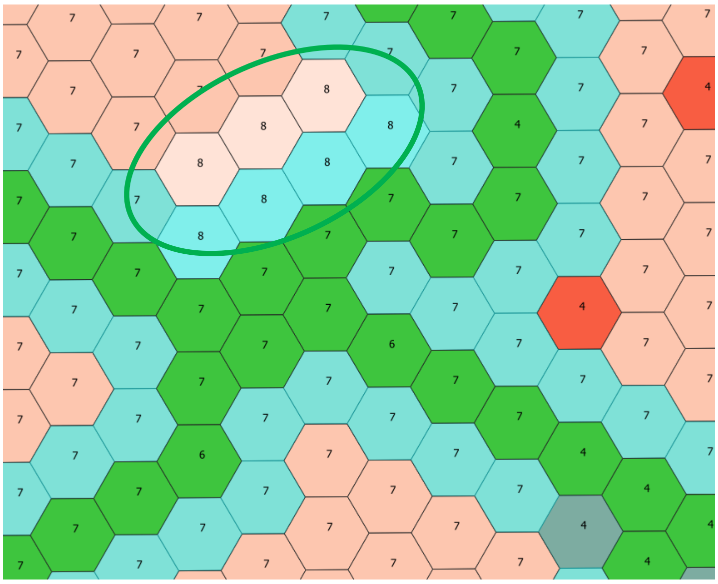
Connecting anchor points within agricultural land.

The suitability of the chosen corridor (value 6) is only marginally better than the surrounding area (value 7).



Connection of three hotspots along stepping stones

Very small forest patches (e.g. church forest, value 4) may not qualify as hotspot but serve as stepping stones in land dominated by agriculture (value 7)



Avoiding barriers

The green hexagons are the corridor route identified by the algorithm. Blue hexagons indicate the targeted width of the corridor (approximately 500m).

The inner GC route entirely avoids barriers (value 8), whereas the fringes of a corridor may include some barriers. If, and how the GC can be implemented in these locations will be determined in the detailed planning process.

In some cases, the final corridor may be narrower to avoid barriers.

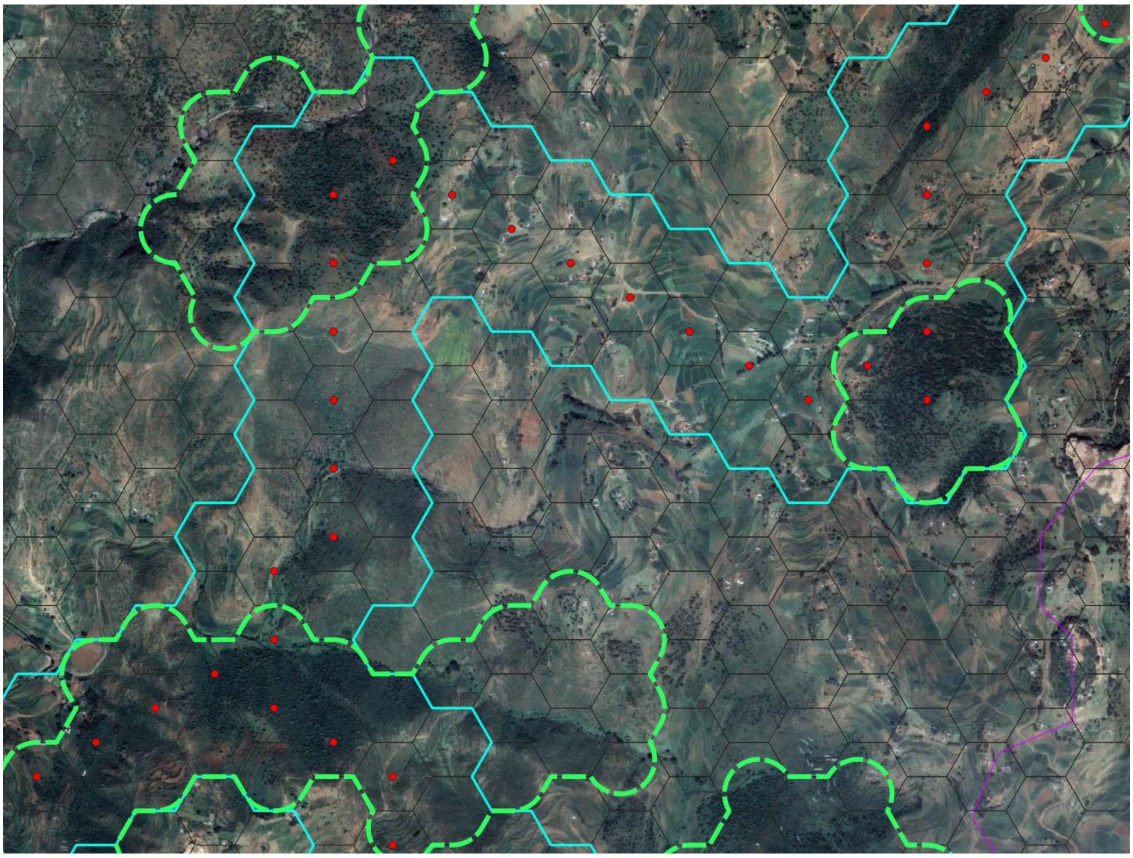
Compilation of the final list of proposed corridors

The output of the GIS (204 corridor routes) was sorted by regional state, overall suitability value. Starting from the top, corridors were evaluated against the most recent satellite image available in the public domain (e.g. Google Earth or Bing maps) to reach the required list of 60 corridor candidates.

The most important criteria for the visual verification were the overall connectivity of habitat and size of biodiversity hotspots to be connected. Corridors that connected larger hotspots were considered more important than those connecting smaller hotspots (but taking into consideration the two forest cover strata). To reflect the interconnectedness of different ecosystems, corridors connecting e.g. lowland with afro-montane vegetation, or wetlands with forest, were given preference were available.

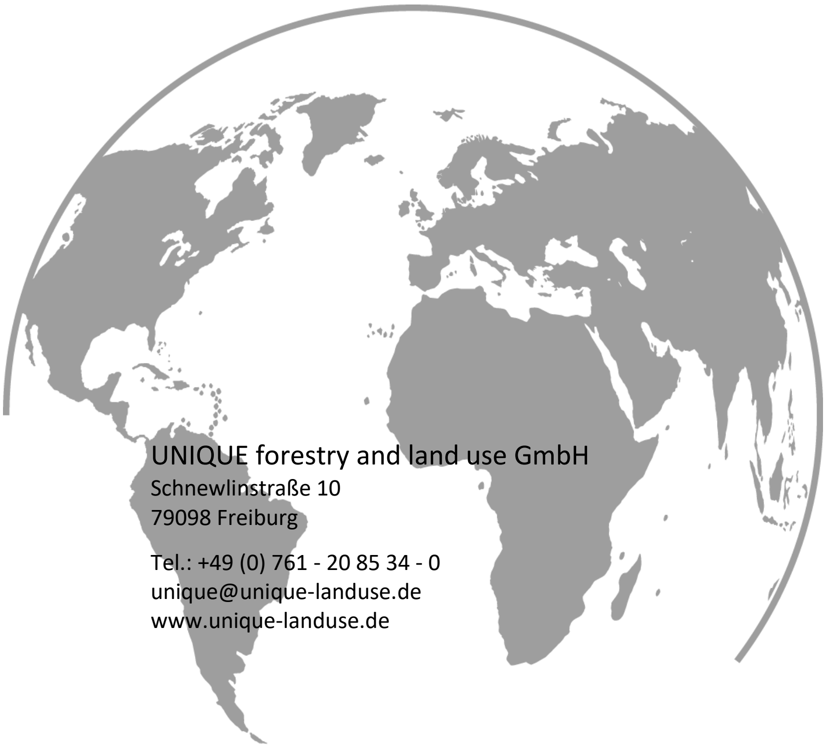
In some cases, the pathways were corrected, taking into consideration additional criteria, such as rivers, ridge lines, or (short) steep slopes which could not be incorporated into the automatic analysis. Some pathways were rejected.

The thus selected corridor routes were expanded to a width of approximately 500m (three hexagons, see below), in order to acquire a reasonable corridor size.



Grey: hexagon layer, Green: hotspot, Red: detected path, Blue: corridor

Example for a proposed corridor route



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