SCALING LAND-BASED MITIGATION SOLUTIONS IN BURKINA FASO

LAND-BASED MITIGATION NARRATIVE CO-DESIGN

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2. Introduction

This report includes a description of a generic nation-wide transition scenario for the implementation of land-based mitigation technologies and practices for the AFOLU sector (agriculture, forestry, and other land use sectors) in Burkina Faso. The report shows the outcomes of a series of research steps that have been conducted in this country since the start of the project in June 2020 until the end of 2022:

First, we performed an initial scoping of key LMTs in the case study country. The scoping assessment resulted in a long list of broad portfolios of different LMTs that could be viable within the various case study countries.

Second, following this long list, we developed a short-list LMT portfolio containing key LMTs that would be the most relevant for a given country context. All case study country partners were asked to propose and validate their LMT portfolio through complementary (policy) literature review and with the help of stakeholder interviews (i.e. external validation by relevant country experts and stakeholders). Ex-ante no specific guidance of criteria for LMT portfolio short-listing was provided to allow for a free and open co-design process with stakeholders. The scoping process and results are presented in section 3 of this report (steps 1 & 2). In Burkina Faso, stakeholder engagement activities were not only limited due to the global pandemic and the language barrier but also because of security threats in the country. For that reason, we hired a local consultant who was able to conduct over 25 stakeholder engagements including researchers, farmers, NGOs, and government agencies. We did a few of these stakeholder engagements online at first and then conducted the majority of engagements on-site in french using the help of the local consultant. Stakeholders played a big role in identifying the relevant LMTs for the country and the opportunities and risks associated with applying these techniques at a larger scale across the country. These conversations were enlightening and helped us to set the priority tasks and challenges that matter most for the local farmers.

Third, after the short-listed LMT portfolios were validated, the LANDMARC case study country partners were asked to develop national scaling narratives or storylines for each LMT included in their portfolio. The assessments focus on climate risks, vulnerabilities as well as socio-economic co-benefits, and trade-offs associated with upscaling LMTs in the case study countries. The analysis is based on a broad range of information/literature sources, and stakeholder consultations conducted. This process is supported through a risk and impact assessment (i.e. an online survey and workshops/seminars/webinars) conducted through the LANDMARC tasks 4.1, 4.2, and 5.2. The results of this analysis are a set of LMT narratives which are presented in a section of this report.

The research steps are designed to enable both an **analysis of the risks and (climate) impacts of scaling up land-based mitigation and negative emission solutions**. As such this report mainly contributes to objectives 2, 3, and 4 of the six LANDMARC key objectives (see Table 1).

Table 1: LANDMARC project objectives.

	Project key objectives
1	Determine the potential and effectiveness of LMTs in GHGs mitigation using Earth Observation (EO)
2	Improve climate resilience of LMT solutions at the local level for large-scale implementation
3	Assess the risks, co-benefits, and trade-offs of scaling up local LMTs nationally
4	Scaling up LMT solutions to the continental and global level to assess the effectiveness
5	Improve current methodologies to estimate emissions and removals for LMTs
6	LMT capacity building and develop new tools and services for decision making

While the results shown in this report represent a mostly qualitative storyline describing the context and impact of scaling up LMTs in a country context, they also enable project partners to proceed with the translation of the outcomes in a manner so that they can serve as direct model input.

Furthermore, these national-level assessments provide a testing ground and empirical basis for the continental, and global assessment of the realistic scaling potential of land-based mitigation and negative emission solutions implemented in Work Packages 6 and 7 of the LANDMARC project (***Objective 4***).

3. Scoping of land-based mitigation and negative emission solutions

3.1 Overview of potential of LMTs in Burkina Faso

3.1.1 Introduction

Burkina Faso constitutes 0.05% of the global emissions and ranks in the list of the per capita emission at 175 out of 188 countries. It is also among the 10% most vulnerable countries to climate change according to the Notre Dame Global Adaptation Index.

Burkina Faso ratified the UNFCCC in 1993 and the Kyoto Protocol in 2005. It also ratified the UN Convention on Biological Diversity (CBD) and the Convention to Combat Desertification (CCD). Burkina Faso is also part of the Green Great Wall Initiative and the 3 S initiative and is committed to integrated solutions for resilience to climate change.

Burkina Faso has developed a number of policy and strategy documents relating to climate change, including:

- The National Strategy for implementing the Climate Change Convention adopted in 2001;
- The National Action Program for Adaptation to Climate Change (NAPA) in 2007;
- The development of a framework NAMA (2008);
- The National Sustainable Development Policy in 2013;
- Strategic Framework for Investment in Sustainable Land Management (SFI-SLM) in 2014;
- The National Adaptation Plan (NAP, 2014);
- The first Nationally Determined Contributions (NDC, submitted 29 September 2015; rectified on 11 November 2016).

National Determined Contributions (NDCs, or CPDN in French) are at the heart of the Paris agreement (COP21, 2015) and describe the countries commitments to reduce their GHG emissions. Prior to COP21 in Paris, Burkina Faso submitted an Intended Nationally Determined Contribution (INDC) to UNFCCC which it later submitted as its first NDC.

Article 4.2 of the Paris Agreement requires Parties to include a mitigation contribution in their NDCs. The Lima Call for Action also invites Parties to consider communicating their undertakings in adaptation planning or including an adaptation component in their INDCs. The NDC of Burkina Faso has both a Mitigation component and an Adaptation component. It highlights the primary interest of Burkina Faso, which is not a large greenhouse gas emitter, as **the improvement of people's capability to adapt** to a significant rise in the average temperature, more severe dry seasons, stronger and less predictable rainy seasons, increased drought, lowering of the groundwater table, and an increased frequency of certain diseases.

In Burkina Faso agriculture (23.94 Mt) and land use change and forestry (8.81 Mt) accounted together for 81 percent of the total emissions (40.25 Mt) in 2017 (Figure 1). Moreover, the 'rural sector' consisting of the water-agriculture-forest-land use subsectors provides the livelihood of more than 80% of the population and is the most vulnerable to climate change, hence the relatively large focus on adaptation in Burkina Faso.

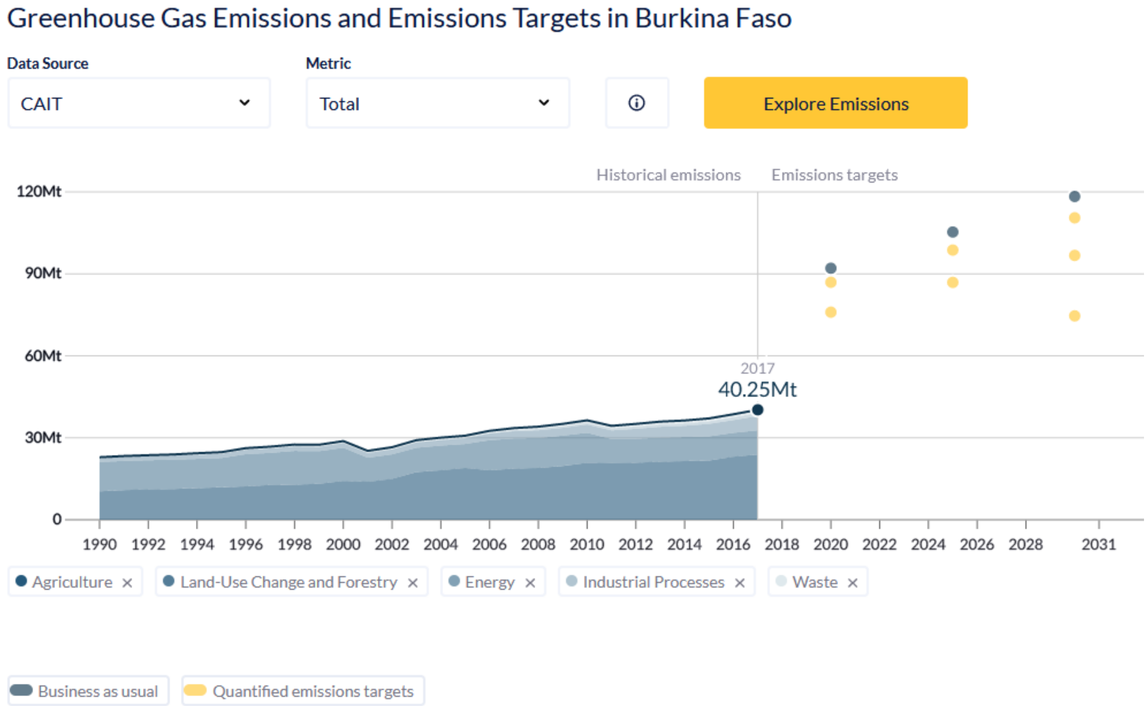

Figure 1 Greenhouse gas emissions and emission targets in Burkina Faso

Source: https://ndcpartnership.org/countries-map/country?iso=BFA.

Under the adaptation component the objective of Burkina Faso is not principally the reduction of GHG (mainly through carbon sequestration) but the enhancement of environmental services such as food security, water and soil conservation, sustainable agriculture. As a bonus to the mitigation component, these projects result in the medium and long term in considerable reductions of GHG, which even exceed the results of mitigation efforts. This is shown in Table 2 which lists the climate targets of Burkina Faso for unconditional and conditional scenarios as well as for an adaptation scenario. Mitigation scenarios are expected to reduce GHG emissions by 2030 by 18.2% while adaptation scenarios will contribute to a reduction in emissions of 36.95% when compared to the Business As Usual scenario.

Table 2 Climate targets of Burkina Faso: reduction in GHG emissions by 2030 for unconditional and conditional mitigation **scenarios as well as for the adaptation scenario as compared to the Business As Usual (BOA) scenario (source: NDC).**

<table>
<tr><th rowspan="3">Category</th><th rowspan="3">Sector</th><th rowspan="2">Estimated total emissions (2030) – BAU scenario[1]</th><th colspan="6">Potential reduction under the following scenarios (2030):</th></tr>
<tr><th colspan="2">Unconditional[2]</th><th colspan="2">Conditional[3]</th><th colspan="2">Adaptation[4]</th></tr>
<tr><th>Gg of CO_2 eq</th><th>Gg of CO_2 eq</th><th>%</th><th>Gg of CO_2 eq</th><th>%</th><th>Gg of CO_2 eq</th><th>%</th></tr>
<tr><td rowspan="6">Emission mitigation reduction</td><td>Solid wastes</td><td>1841</td><td>-</td><td></td><td>76.3</td><td>4 %</td><td></td><td></td></tr>
<tr><td>Transportation</td><td>6,925</td><td>29.3</td><td>0.4 %</td><td>2911</td><td>42 %</td><td></td><td></td></tr>
<tr><td>Electricity production</td><td>4,191</td><td>493.04</td><td>11.7 %</td><td>162.80</td><td>4 %</td><td></td><td></td></tr>
<tr><td>Residential</td><td>230</td><td>49.71</td><td>21.65 %</td><td>49.35</td><td>21 %</td><td>6.5</td><td>2.83%</td></tr>
<tr><td>Energy in the manufacturaing industries</td><td>363</td><td>10.90</td><td>3.00 %</td><td>7.30</td><td>2 %</td><td></td><td></td></tr>
<tr><td>Industrial processes</td><td>1,348</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="4">Land management solutions with LMT potential</td><td>Agriculture-water</td><td rowspan="4">103,424</td><td rowspan="4">7,236</td><td rowspan="4">7 %</td><td rowspan="4">10,560</td><td rowspan="4">10 %</td><td>5,150</td><td rowspan="4">42.25%</td></tr>
<tr><td>Animal husbandry</td><td>21,630</td></tr>
<tr><td>Biomass energy</td><td>1,220</td></tr>
<tr><td>Forests and changes in land use</td><td>15,700</td></tr>
<tr><td></td><td>Total</td><td>118,323</td><td>7,808</td><td>6.60 %</td><td>13,766</td><td>11,60 %</td><td>43,707[5]</td><td>36.95 %</td></tr>
<tr><td colspan="2">Investment (million US$)</td><td>-</td><td colspan="2">1.25</td><td colspan="2">756</td><td colspan="2">5805</td></tr>
</table>

Table 3 lists the different actions per sector (sustainable land management, forestry, energy, environmental education, and food) identified in the NDC. The focus in Burkina Faso is on land management practices in forest land, cropland, and grassland, and in particular on the dynamics of agricultural land. Agricultural land expansion mainly occurs at the expense of natural areas and forests.

[1] A "trend" scenario (Business as Usual - BAU), which corresponds to continuation of the past under the assumption that economic development continues without interruption. The chosen reference year is 2007.

[2] What countries could implement without any conditions and based their own resources and capabilities (financing acquired or being acquired)

[3] What countries would undertake if international means of support are provided, or other conditions are met (without any acquired financing)

[4] Not mandatory

[5] The adaptation scenario aims, among other things, to restore and develop 5,055 million ha of degraded land, corresponding to 55% of the total current area of degraded lands.

The dynamics of agricultural land are expected to be affected by land-demanding mitigation options such as afforestation, avoided deforestation, improved agricultural management and bioenergy crop production (Soest, Elzen, Forsell, Esmeijer, & Vuuren, 2018).

For example, the objective of the Forest Investment Program (FIP) – one of the larger programmes in Burkina Faso with a mitigation and adaptation component - is to reduce the direct and indirect factors of deforestation and degradation of forest and woody areas in order to enhance carbon sequestration and improve the life conditions of rural populations. The approach is communal and participative for the protection of natural resources and taking into account social aspects. The practices are grouped in 3 categories:

- Practices that improve carbon sequestration: reforestation, afforestation, conservation, restauration
- Practices linked to land management and land tenure security
- Practices aimed at decreasing forest degradation and deforestation

Table 3: Sectors identified in the NDC (source: https://africaadaptationinitiative.org/ndc/countries/burkina-faso/)

Sustainable Land Management	• Promotion of sustainable land management – improving access to climate information • Cultivation of early or drought-resistant varieties • Implementation of water and soil conservation techniques • Practice of integrated soil fertility management • Development of master plans for water management • Development of water reservoirs: construction of modern wells, high-flow boreholes, dams; development of ponds; stream diversion • Development of grazing water sources and points • Delimitation and development of grazing zones • Combatting the silting of water sources • Implementation of water-efficient irrigation techniques • Development of research programmes on the resilience of forest, wildlife and fish species • Rehabilitation and preservation of wet areas
Forestry	• Implementation of good forestry and agroforestry practices (selective cutting of firewood, assisted natural regeneration, controlled land clearing, etc.) • Protection of water courses and water sources • Practice of agroforestry for sustained management of natural resources • Community and participative management of forest, wildlife and fish resources
Energy	• Diversification of energy sources (solar, wind, biogas) • Promotion of energy-saving technologies in industry and construction
Environmental education	• Development of environmental education in both formal and informal teaching systems
Food	• Improvement of food processing and preservation methods

3.1.2 Land management practices

Tackling deforestation and restoring degraded land are key pillars in Burkina Faso to reduce GHG emissions and the human and environmental vulnerability to climate change. It requires to take a holistic approach as forests, agriculture, pastoralism and water management are strongly intertwined in the country. In that regard, carbon sequestration programs have proposed diverse but integrated LMTs to be implemented in different sectors ranging from sustainable forest management to agricultural development and bioenergy. Through direct or indirect approaches, these various land-based activities aim at decreasing pressure on forests, (re)plant and restore land health while improving the potential for farming and cultivating.

Practices linked to sustainable land management

Sustainable land management practices in drylands increase agricultural productivity and contribute to climate change adaptation and mitigation. Possible integrated crop, soil and water management measures include crop diversification and adoption of shorter-cycle, more drought-resilient crops, reduction of tillage, reduction in the number of herds, adoption of improved irrigation techniques (e. g., drip irrigation) and moisture conservation methods (e.g., rainwater harvesting according to indigenous and local practices) and maintenance of vegetation and mulch (Faye, et al., 2019).

Practices that improve carbon sequestration: reforestation, afforestation and protection

To reach negative CO_2 emissions, afforestation (planting trees where there were previously none) and reforestation (restoring areas where the trees have been cut down or degraded) are commonly used options. The plantation of agroforestry and fruit trees species is an example of practice used for reforestation and afforestation. Planting these species also restores the vegetation and soil biodiversity (The Forests Dialogue, 2011). The establishment of agroforestry parklands (e.g., shea trees) on farmland, fallow land or rangeland is another afforestation practice with high potential for carbon sequestration and return for the farmers (World Bank, 2013). It requires to invest in building tree nursery infrastructure and select the most fitted species. The creation of conservation zones is a third effective option to reduce deforestation and implement restoration measures. The zones are delimited using physical markers and categorized as “Classified”.

The forest sites selected for the (re)plantation, restoration and protection measures are sites that hold a high carbon sequestration potential and are rich in natural resources and biodiversity while having undergone depletion from the following drivers: agricultural and farming area expansion, wood cutting for fuel or for farming practices, overexploitation of non-timber products and bushfires. Other significant co-benefits from these practices include wildlife preservation, watershed and soil conservation, prevention of soil erosion, etc. (World Bank, 2013). In order to make these investments sustainable, the carbon sequestration programmes also focus on improving forest governance, securing the conservation sites and on supporting socio-economic infrastructure for the benefit of neighboring municipalities.

Practices aimed at decreasing forest degradation and deforestation

Between 1992-2002, the deforestation rate in Burkina Faso was estimated at 105 000 ha/year while the degradation rate of woodlands and forests reached 50 000 ha/year. Less information is available since then but these rates are assumed constant during the following years (World Bank, 2013). Creating irrigated spaces, delimitating grazing areas and building modern sylvo-pastoral infrastructure are among the many LMTs proposed to help developing the agro-sylvo-pastoral sector while reducing tremendously the pressure on the nearby forests. For instance, by avoiding wood reliance, infrastructure (e.g., vaccination parks, water holes and pastoral wells) in metal or stone prevent cutting thousands of trees while providing a safer environment for the cattle and the farmers.

In the energy sector, one notable LMT is the promotion of biodigesters and improved cook stoves in rural households close to nature reserves. The adoption of biodigesters holds a climate change mitigation and attenuation effect by: proposing an alternative to the use of fuelwood, charcoal and fossil fuels for lighting and cooking; capturing the methane and carbon emanating from organic waste decomposition and use them as biogas for renewable energy. As an additional advantage of the technology, the compost resulting from the organic matter breakdown can be used as soil fertilizer, which in turn supports agricultural intensification (Fair & Sustainable Consulting , 2019).

3.2 Determining the LMT scope for national level simulation modelling

In Table 4 , we present the short list of national LMTs that are relevant for the scoping analysis. These LMTs were selected from the 2015 mitigation and adaptation actions proposed in the frame of the NDC. Reasons for the selection and expected outcomes are presented below.

Table 4: Long listing of relevant land based LMTs

LMT	Specification	Included in national LANDMARC LMT portfolio
BECCS	-	N
Biochar	-	N
Forest land	Reforestation, afforestation and forests classification	Y
	Sustainable land management practices on forest land (e.g., Assisted Natural Regeneration)	Y
	Reduced deforestation by promoting improved cook stoves and biodigesters	Y
	Degraded stream banks rehabilitation	N
Cropland	Sustainable land management practices on agricultural land (e.g., agroforestry parklands and soil fertility restoration such as stone barriers, zai pits, half moons)	Y
	Agricultural intensification (e.g., organic manure, low lands)	N

- **Reforestation, afforestation and forests classification**

(Re)planting using local species and expanding the classified forest domain are at the heart of Burkina Faso's main plans and programs (e.g., FIP, REDD+) and are expected to have a strong impact on carbon stock. The NDC adaptation scenario aims at creating 900,000 ha of reforested and conservation areas and developping 450,000 ha of classified forests in the forest/change in land use sector, both projects expected to cumulate 14,000 Gg of CO_2eq sequestrated per year. It should be noted that in Burkina Faso, forests can be private or public (owned by the state or by decentralized local collectives). Public forests can be themselves categorized as "classified" or "protected". Classified forests are subject to more restrictions regarding their use and exploitation for the purpose of environmental conservation. Despite the ambitious INDC target, land pressure however is currently a limiting factor to the expansion of classified forests in the country.

- **Sustainable land management practices on forest land**

  In Burkina Faso, several land management techniques exist to restore degraded forests and woody spaces. Techniques such as fencing, combined or not with Assisted Natural Regeneration (ARN), have shown results as successful as reforestation efforts. Building fences prevents herd animals to graze young trees in their first years of growth. ANR is a low-costs practice aimed at accelerating vegetation regeneration rather than replacing it. It calls for an active participation of the population to recover over-exploited land and manage the regrowth of the field. In forestry, the ANR technique enables land conservation and improvement (increased number of trees and diversity), the maintainance of soil fertility, and livelihood improvements (with the exploitation of non-timber products). Part of the NDC adaptation targets is the establishment of 800,000 ha of ANR (in 200 rural communes) for an estimated amount of 1,600 Gg of CO_2eq saved every year.

- **Reduced deforestation by promoting improved cook stoves and biodigesters**

  The vulgarization of improved cook stoves and biodigesters has been at the heart of Burkina Faso's ambitions for several years already. The FIP investments of the African Development Bank resulted for instance in 4282 cookstoves households installation. The ambition under the adaptation plan is to produce and distribute 540,000 improved cook stoves to save 610 Gg of CO_2eq, and to save a similar amount by improving cook stoves for brewers. Regarding biodigisters, the National Biodigester Program (PNB-BF) has supported the construction of 18000 biodigesters across all 13 regions of the country between 2010 and 2018. In 2019, 1500 biodigesters were planned to be built through the PNB-BF – FIP cooperation although reported numbers for this year show that this target wasn't met. In 2017 and 2018, Burkina Faso organized the International Conference of Biodigester Technology (CITBIO) gathering several African countries such as Benin, Ivory Coast, Guinea, Niger, Senegal, Togo and Mali as well as national and international organizations. The objective of the conference being to work towards an African partnership for the promotion and widespread implementation of biodigesters technology. Under the adaptation scenario, Burkina Faso plans to equip 25,000 households with operating biodigesters that fertilize 750,000 ha of cultivable land, resulting in 1,800 Gg CO2eq saved. The dissemination of biodigesters and improved stoves is however limited by the related costs and reliability on external financial support.

- **Sustainable land management practices on agricultural land**

  Sustainable land management, which includes halting land degradation and restoring soil fertility has been identified in the NAP as top priority measures to mitigate climate change effects while enhancing crop productivity. To do so, the NAP recommends the implementation in Burkina Faso of a set a diverse actions including the diversification of crops (e.g., increase drought-resistant varieties), agro-forestry, assisted natural regeneration, water and soil conservation and restoration techniques (e.g., the establishment of stone barriers, terraces, small dikes, the use of zai pits and half-moons, etc.) but also the use of living hedgerows, sub-soiling and preventing bush fires. In total, the following adaptation measures: restoring and maintaining fertility in 1,575 million ha of cropland through soil and water conservation techniques; restoring 105,000 ha of degraded land for agricultural production through the construction of 10,000 ha of micro-watersheds, should save the equivalent of 5,106 Gg CO_2 per year in 2030.

The rationale for excluding the other LMTs from any further national scenario scaling analysis is provided below:

- **BECCS and biochar**

  NETPS in Burkina Faso focus on land management practices. We could not find any implementation of BECCS in the country nor are they described in the NDC. Small-scale biochar application is found in urban vegetable production in the capital Ouagadougou and experimental in other areas, but is not yet part of government strategies.

- **Degraded stream banks rehabilitation**

  Stream banks rehabilitation and protection using a hedgerow barrier system are part of the soil and water initiatives recommended by the NAP and the NDC. In the NDC, this LMT obtained however a lower weighted prioritisation score (based on green growth and maintenance of natural resources, generation of wealth, ease of access/adoption of the technology) than the other LMTs listed in Table 3. Given the relatively small-scale (2000 ha) and impact (60 Gg of CO_2 eq) and complexity of relating rehabilitation and protection to its impact on the catchment, we suggest to exclude the degraded stream banks rehabilitation from the analysis.

- **Agricultural intensification**

  The intensification of agricultural activities has the primary role of increasing crop production while reducing cropland expansion. Relevant techniques enabling intensification in Burkina

Faso are the application of organic manure and compost to fertilize crops. These techniques that recycle carbon and store it in the soil have shown to be very profitable in the country. Other best practices are the establishment of new irrigation techniques (e.g., pressured drip irrigation) and the development of low lands areas for intensive rice production. The INDC commitments include the development of 15,000 ha of low lands and irrigated areas for intensive rice cultivation, possibly resulting in 44.4 Gg of sequestred CO_2. While these intensification techniques present many advantages, their carbon impact is more indirect and somewhat lower than the ones selected for the scoping analysis and for this reason we propose not to include them in the short list.

3.3 Discussion on short-listing LMTs

3.3.1 Forest and changes in land use sector

According to the World Bank, degraded forest lands and associated restoration efforts hold the highest potential for carbon sequestration in Burkina Faso. It is without surprise that the country has set ambitious NDCs in the forests/change in land use sector in its 2030 adaptation scenario. While the climate benefits of the LMTs listed in Table 3 within that sector would be tremendous, their implementation requires the provision of external support (e.g., capacity building) and fundings (e.g., because of high investment costs or low economic profitability). The requirement for external financial support is indeed often explicitly expressed as a necessary condition for successful NDC implementation. Burkina Faso clearly describes it as a “constraining determinant” with both the mitigation and adaptation actions heavily relying on international financial resources. Furthermore, Burkina Faso’s private sector will contribute almost 50% of the financing. What this amount translates to is not explicitly specified.

While political commitments have been strong in Burkina Faso during the past 30 years, achieving Burkina Faso’s NDCs also heavily relies on political stability and a robust governance structure, which still have to be further established. Frequent terrorist attacks, especially in the northern part of the country have increased the vulnerability of the populations and are an important barrier to the developments of livelihood and environmental improvements in the impacted regions.

Another factor of importance is the further enabling of local community engagement. Building on the results of the FIP will allow us to adopt successful approaches and techniques that improve and decentralize forest and woodland management programs. For instance, protecting investments through land tenure security and providing local actors with the necessary capacity to take ownership of forests and woodlands management are key solutions to focus on.

It is interesting to note that Burkina Faso’s semi-arid forests (tropical dry forests and woodlands) are widespread in the world – we count over 500 million hectares of semi-arid forests over the globe. The potential for replication and upscaling across the African continent and other countries is therefore significant (World Bank, 2013).

3.3.2 Land management dynamics

Since the 70s, the short-listed LMTs related to soil and water conservation practices have already proven themselves effective in improving forest density, soil structure, biodiversity ,and crop productivity in some regions of the country (Clement Nyamekye, 2018). However, one limitation to their extensions is linked to a lack of long-term land ownership and gender issues. In Burkina Faso, parcels of land are loaned or leased to farmers. Because of this, farming approaches usually favor practices that generate fast returns rather thathanose requiring long-term investments (Clement Nyamekye, 2018). In addition, Burkina Faso has deeply rooted gender norms, preventing most women farmers to own land and to have the same opportunity as men to take part in land restoration activities. These issues are being tackled by NGOs and programs like the FIP. They aim at improving land tenure security but also providing professional training and improved access to financing to women as well as increasing their participation in land use planning and management activities. Strengthening these efforts will therefore enhance the adoption of land conservation and regeneration techniques and their associated carbon sequestration benefits.

4. Co-design of LMT narratives

4.1 Introduction

The LMTs discussed here are the primary land-based techniques and practices implemented in Burkina Faso to reduce GHG emissions and climate change vulnerability. They are considered the most relevant in terms of carbon sequestration potential and co-benefits on the local, national, and regional levels. These LMTs are part of the country's commitments for 2030 and mainly aim at planting trees, restoring degraded land, and reducing pressures on forests:

- Reforestation, afforestation, and forest classification.
- Sustainable land management practices on forest land with a focus on Assisted Natural Regeneration (ARN).
- Reduced deforestation by promoting improved cookstoves and biodigesters.
- Sustainable land management practices on agricultural land with a focus on agroforestry parklands and soil fertility restoration such as stone barriers, Zai pits, and half-moons.

Stakeholder engagements played a key role in identifying the drivers of deforestation and forest degradation in Burkina Faso. It helped us to understand the co-benefits and risks of implementing different LMTs across the country. We found that the degradation of ecosystems in Burkina Faso has been consistent, often explained by climatic deterioration and increasing demographic pressure on natural resources. The sources of deforestation or forest degradation are predominantly anthropogenic, such as agricultural and livestock production, and exploitation of resources for energy and mining. In Burkina Faso, forest loss primarily occurs as a result of uncontrolled bushfires, fuelwood harvest, encroachment into forest areas for agricultural production (i.e. for crops and livestock), and mining expansion. These stressors are exacerbated by population growth, poverty, and urban development, and climate variations. Despite this, Burkina Faso's Initial National Communication to UNFCCC identifies its area of land use, land-use change, and forestry (LULUCF) as a net sink. Overall, the stakeholder engagements opened the gate for us to feel the challenges that the local farmers face and the technical challenges that sometimes prevent them to apply LMTs a at larger scale.

4.2 Reforestation, afforestation, and forests classification

4.2.1 Introduction

In Burkina Faso, deforestation and the exploitation of deforested land are the main emitters of CO_2. As explained in more detail in the Step 1 section of this document, the main drivers of deforestation in Burkina Faso are related to land expansion for agriculture and livestock farming, bushfires, overharvesting for fuelwood and non-timber products as well as gold mining. Since the 191970sBurkina Faso has implemented several initiatives to maintain and increase its forest cover. Among these initiatives, priority is given to reforestation, afforestation, and forest protection. Despite the effort, the measures taken aren't currently enough for carbon sequestration to equal or surpass CO_2 emissions. According to the Ministry of the Environment, Green Economy, and Climate Change (MEEVCC), the area of planted forests roughly corresponds to 10% of the surface of land deforested each year only. In this section, we will discuss the context of the implementation of reforestation, afforestation, and forest classification in Burkina Faso.

4.2.2 Policy context

Forest governance can be defined as the aggregate of rules, policies, institutions, and practices aimed at ensuring the implementation of the principles of transparency, accountability, and participation within the sector. As such, it concerns how the institutions acquire and exercise their authority in the management of forest resources; with transparently developed policies; a bureaucracy that operates according to a professional ethic; an executive that is aware of their actions, and a strong civil society that participates in the decisions that relate to this sector. In Burkina Faso, the categories of actors with responsibilities for forest governance are state structures, collectivités territoriales , the private sector, rural communities and partner organizations. For the 2020 Global Forest Resources Assessments (FRA), the FAO and Burkina Faso prepared an evaluation on the country's forest resources. The assessment is based on the collection of the country's existing reports and complemented with the use of satellite remote sensing for the identification of land use and land use change. In the 2020 FRA, the main policy and strategy documents guiding the sustainable management of forest resources in Burkina Faso are listed:

- Accelerated Growth and Sustainable Development Strategy (SCADD).
- National Sustainable Development Policy (PNDD).
- National Environmental Policy (PNE).
- National Forest Policy (PFN).
- National Rural Land Security Policy (PNSFMR).
- Decentralized Rural Development Policy Letter (LPDRD).

For the implementation of these policies, the following documents dealing with the preservation of forest resources have been adopted:

- National Rural Sector Program (PNSR).
- Ten-Year Action Plan for the Environment and the Living Framework (PDA / ECV).
- National Action Program to Combat Desertification (PAN / LCD).
- National Forest and Wildlife Resources Management Program (PRONAGREF).
- Burkina Faso's National Strategy and Action Plan on Biological Diversity.
- National Strategy and the Action Plan for the National Strategy for Fire Management in Rural Areas.
- National Plant Production Strategy.
- Environmental Information Management Program.

Forest classification is done at the state level. Reforestation and afforestation efforts are however implemented by the villagers and rural communities. Efforts are led by state and non-state (NGOs) actors. Funding is primarily provided through international projects under programs such as the Forest Investment Program (FIP) under the Strategic Climate Fund (funded by among others the WB's IBRD and AfDB).

4.2.3 Current land use and potential land-use competition

The agro-ecological zones of Burkina Faso reflect the climatic divisions of the country, with the vegetation cover becoming denser from the North to the south. Forest areas in Burkina Faso are made up of land stocked with trees and/ or shrubs including agro-forestry parks (Figure 1). The most obvious change in Burkina Faso's land cover over the last decade is the major expansion of croplands (Figure 2). Reforestation programs have started in 1973 in Burkina Faso and have cumulated 52,650 ha of planted surface within the period 1973-1999, although it is not clear whether the plantations have been maintained or converted to another land use since then (Ouedraogo, 2000). According to the FRA's assessment, the extent of the Burkinabe forests has undergone an annual decrease of 0.77% between 2010 and 2020, showing a steeper deforestation rate than during the periods 1990-2000 and 2000-2010 (see Figure **2: Locations of parks and reserves in Burkina Faso (source: USGS)**Natural forests have decreased in extent in the last 20 years due to a conversion to other land uses (woody areas, agricultural land and degraded forests) while planted forests have increased, in a lesser extent, due to sensibilization programs encouraging reforestation and afforestation. The 2020 FRA reports a cumulative planted area of 198,303 ha between 2000 and 2018. Annual details are presented in Figure 3.

It is worth to note that estimates of Burkina Faso's total forest cover vary between sources, many of which use different methods of assessment. For example, the Ministry of the Environment (at that time the Ministry of Environment and Livelihoods) shared that forest formations (i.e. open forest, gallery forest, shrubland, wooded savanna, steppe) covered 13,305,238 ha in 2002, or 48.52% of the national territory. However, FAO statistics in 2020 reported 6,216,000 ha of forest cover in Burkina Faso, accounting for approximately 23% of the total land area, and 'other wooded lands' accounting for about 18%. This mainly consists of acacia bush in the north (Sahelian regions), and savannas, shea (Vitellaria paradoxa), néré (Parkia biglobosa), tamarind (Tamarindus indica), baobab (Adansonia digitata), dry forests and gallery forests in the central belt and the south (Sudanian type region). Shrublands represent the most common type of land use, followed by fallow and agroforestry areas, and wooded savannas.

In Burkina Faso, land is used for urban development, agriculture, grazing, mining, forest management and exploitation. Pastoralism is predominant in the north but occurs throughout. Shrublands represent the most common type of land use, followed by fallow and agroforestry areas, and wooded savannas. In terms of legal status, forest types are divided into reserve estates (25%) and protected areas (75%).

Forest reserve estates (Figure 2) cover approximately 3,900,000 ha, or 14% of the country, including national parks (390,000 ha), nature reserves (2,545,500 ha) and forest reserves (880,000 ha)

Table 1: Forest extent in Burkina Faso (FAO, 2020).

Forest area (1 000 ha)				Net annual change					
1990	2000	2010	2020	1990-2000		2000-2010		2010-2020	
				1000ha/yr	%	1000ha/yr	%	1000ha/yr	%
7717	7217	6717	6 216	50.0	-0.67	50.0	-0.72	50.0	-0.77

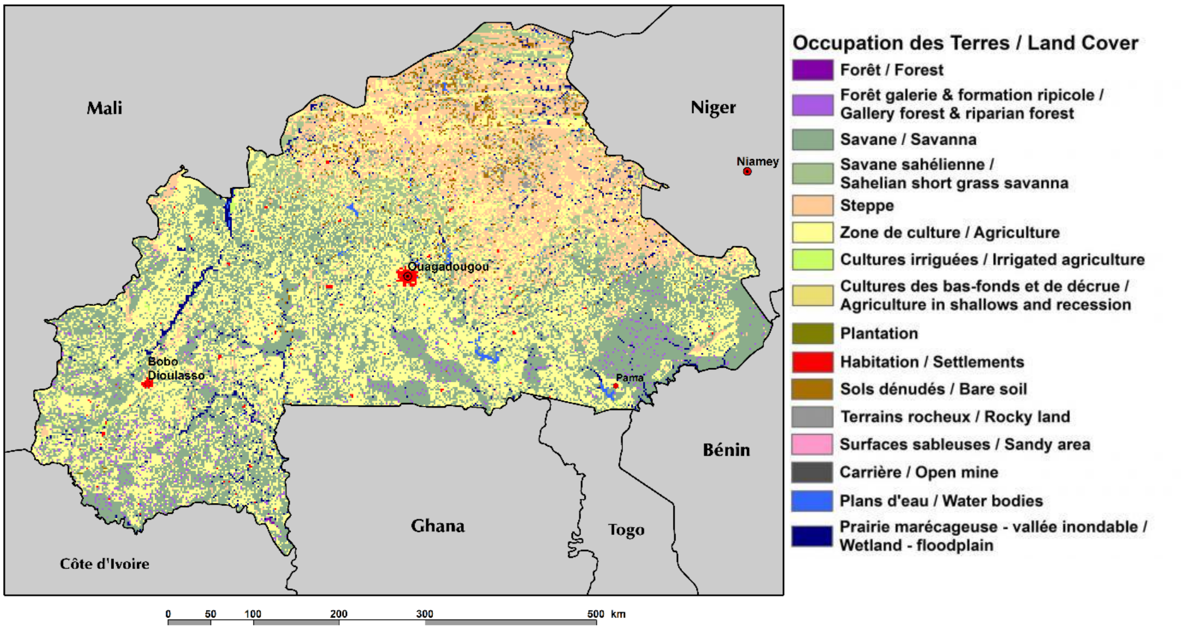

Figure 1: Different Land cover types in Burkina Faso in 2013 (source: USGS)

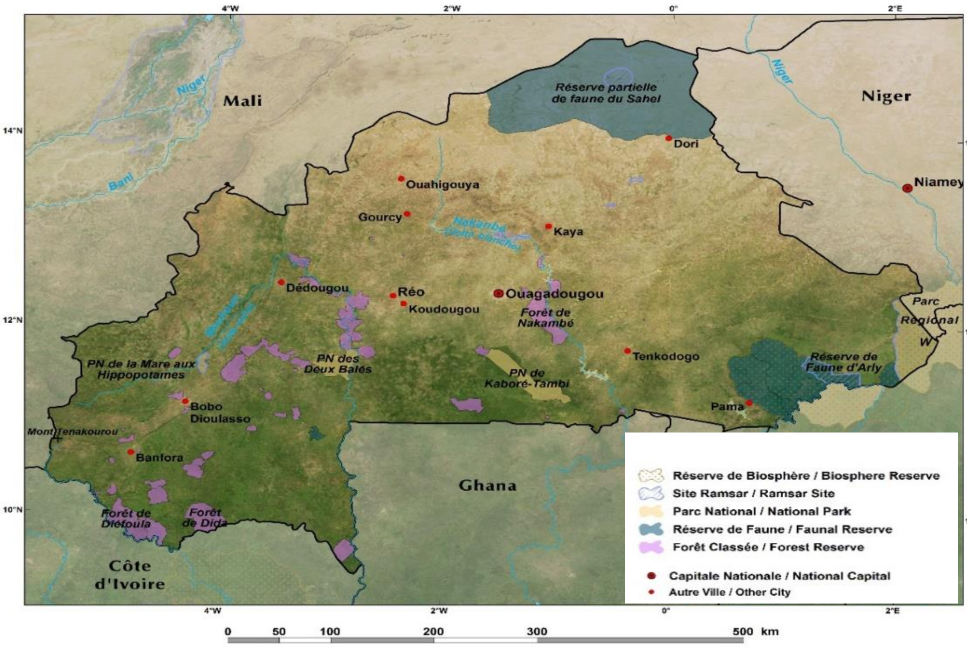

Figure 2: Locations of parks and reserves in Burkina Faso (source: USGS)

In Burkina Faso, the rural sector employs around 80% of the active population according to the World Bank and is responsible for 35% of the Gross National Product (Hermann, et al., 2016). Growing and exporting commercial crops is particularly seen as critical for the macroeconomic stability of Burkina Faso. Cotton for instance, is the main cash crop of the country and has an important impact on government's revenues. As a result, rural agriculture has been developing unsustainably, pushing for land expansion at a rate of 3% per year (World Bank, 2013). In addition, pastoral activities also compete with forest restoration and maintenance. Livestock products are Burkina Faso's third most profitable export, nationally for dairy products, internationally for meat and hides. As a result, livestock breeding and especially grazing have called for more forest clearing. Illegal grazing by herd cattle can also occur in classified forests in which regulations only recognize the right to harvest fruits, dead wood, and medicinal plants for subsistence, causing land degradation (Hermann, et al., 2016). Finally, gold mining is the last of the main competing land uses posing threat for the state of the Burkinabe forests. Mining for gold makes up 4% of the national GDP and is in expansion with more artisanal sites being created. The mining sector has disastrous consequences for the environment as it leads to deforestation, soil degradation and GHG emissions from excavation and transportation (Hermann, et al., 2016).

Figure 3: MEDD reports on the evolution of the surface of planted forests (FAO, 2020).

4.2.4 Climate risks & sensitivities

Drought, precipitation, and temperature are strong drivers of tree growth and /or mortality in tropical dry forests (Siym, 2020) like in Burkina Faso. Also, forests in Burkina Faso are particularly subject to bushfires. Bushfires occur with very dry herbaceous vegetation and are more common with the increased temperatures and droughts brought with climate change. The analysis of the situation in Burkina confirms that forest and woodland resources are vulnerable to a range of environmental factors including the impact (direct or indirect) of climate variability and change, the pressure from a growing population, the weaknesses and lack of performance of institutions, gaps in the legal and regulatory framework for local forest management as well as a range of social and economic factors.

Direct drivers of deforestation and forest degradation include among others the following: Livestock activities: cattle, goat and sheep husbandry; Agricultural expansion: mostly cotton production and food production; Overharvesting of Firewood due to increasing demand; Overharvesting of Non-timber forest products; Bush fires; and Gold mining. Proximate drivers includes the following: Economic and Demographic factors (growth in impoverished rural populations who depend on forestry products for survival), Land management (delays in implementing land tenure reforms, insufficient tools for sustainable land use planning and management, insufficient enforcement), Technical capacities and Knowledge (lack of capitalizing on good forestry practices, weak control, lack of resource knowledge), Overall capacity weakness of stakeholders (at decentralized and centralized level), Governance (difficulties in enforcing laws and regulations relating to the forestry sector).

Reforestation, afforestation and forest classification are tools to strengthen the resilience of ecosystems and population to climate change by offering protection against landslides and erosion, re-establishing ecosystem functions as well as restoring biodiversity. Most commitments and forest restoration programs have included plans to reduce uncontrolled fires.

4.2.5 Economic implications

In Burkina Faso, the exploitation of forests for non-timber products plays a major role in the alleviation of rural poverty. Forest-based livelihood activities are concentrated in the Sudanian-type ecozones. These include the production of fuelwood and charcoal, the collection and trade of NTFPs such as shea (Vitellaria paradoxa), néré (Parkia biglobosa), baobab (Adansonia digitata) and gum Arabic (Acacia laeta, Acacia senegal). The extent of fuelwood collection and charcoal production in a given area depends on tree density and population. Higher population densities and higher tree densities both seem to favor increased fuelwood production. Maintaining healthy forested areas is a way to strengthen rural income and GDP development. In terms of implementation costs of the LMT, the investment needed for the creation of 900 000 ha of forest conservation space in the INDC adaptation scenario was estimated at 504,000,000 USD in total (60 USD per beneficiary). The development of 450,000 ha of classified forests is an extra 252,000,000 USD in investment with a ROI of 109% for the national economy by 2030, making it a profitable intervention (see Table).

Table 2: Burkina Faso INDC adaptation actions on reforestation, afforestation and forest classification and estimated cost and effect by 2030 (Burkina Faso, 2015).

INDC adaptation projects	Investment cost [USD]	Tons of CO_2 saved / year	Cost [USD]/ tons of CO2 equ. /ha/year	ROI [%]
Creation of 900 000 ha of forest conservation space	504,000,000	9,360,000	$5.98291e^{-5}$	-
450,000 ha of classified forests	252,000,000	4,680,000	0.000119658	109

4.2.6 Co-benefits and trade-offs

On the environmental side, co-benefits would be related with soil fertility management, erosion control, watershed protection and biological diversity (FIP, 2012). On the economic side, co-benefices are related with employment, revenue increase for the local populations, and boosting the broader local and regional development. On the social side, FIP activities would have a positive impact on gender equity as it will contribute to improving the social and economic status of women: Initiatives should result in time savings from activities, such as fuel wood collection (freeing up time for other tasks, including children's education) and in revenue generation. The FIP would also have a positive impact on agricultural productivity through providing support to agroforestry, reforestation and the protection of forested areas (FIP, 2012).

The LMT has the main purpose of enhancing carbon stocks in trees however, forests in Burkina Faso also holds direct and indirect economic benefits as well as non-economic ones. The Burkinabe economy relies indeed heavily on forest-based activities (e.g., timber and charcoal sales) but also on the food (e.g., fruits) and medicinal products (e.g., Vitellaria paradoxa used for skin diseases and typhoid fever) offered by forests and woodlands. Other important environmental services of forests are biodiversity safety (e.g., pollination) and watershed protection. On the social level, larger forest cover also means higher income for women in rural villages whose responsibilities lies with the exploitation of non-timber products.

As a trade-off, plantations if they are commercial, are usually made of a monoculture. This provides fast and clear economic return and allows to provide biomass fuel without pressuring existing forests. However, the biodiversity is much lower than in natural or regenerated forests (Belem, et al., 2017).

4.2.7 Risks associated with scaling up

The main barrier to the scaling up of the LMT is the lack of interest of the local villagers to maintain and protect collective plantations. Reforestation, afforestation and classification practices are based on top-down approaches and often applied on land that is state owned. The lack of ownership coupled with traditions have brought project failures on the long-term in spite of high financial investments (Langewiesche, 2004). Securing land tenure is necessary to provide long-term benefits to holders and thus incentives to conserve forests. Carbon project should primarily focus on poverty reduction and local development to avoid getting disconnected from the people concerns.

When scaling up to other countries, it should be taken into consideration that while in some country deforestation is mostly caused by the international market, most of the forest degradation in Burkina Faso is linked to local drivers and poverty (FIP, 2012).

4.2.8 Research gaps

There are currently no monitoring procedure of the impacts of degradation and restoration efforts at national level. Data on deforestation rate vary from one source to another and reports on the LMT implementation are inconsistent. For example, based on the FAO data, the annual deforestation rate would be about 75,000 ha/year (from 7.72 million ha to 6.22 million ha over 20 years). However, the government estimates the deforestation rate at 107,626 ha/year – almost double the FAO's estimate. This large discrepancy is an indication of the paucity of forest statistics in Burkina Faso and the difficulty to precisely define the forested land since there is a continuum between forest, wooded savannah and grassy savannah. The deforestation rates for Burkina Faso quoted in the literature are therefore numerous and they vary (Westholm and Kokko, 2011), including estimates of 15,000 ha/year, 65,000 ha/year, 80,000 ha/year, 105,000 ha/year, and 107,626 ha/year.

4.3 Sustainable land management practices on forest land (e.g., Assisted Natural Regeneration)

4.3.1 Introduction

FAO defines the Assisted Natural Regeneration (ARN) as "a biological process that can be assisted and managed to increase forest cover and achieve the recovery of the native ecosystem or some of its functions". The aim is the recovery of forest ecosystem, structure and biodiversity using natural techniques. The ARN consists of a set of interventions that accelerate the natural process of tree growth by preventing disruptions from bushfire, animal grazing, human activity (e.g., wood harvest) and competition with other plant types (e.g., weeds). ARN has the advantages of being simple, cheap and providing diverse and well-adapted tree species. (FAO, 2019).

4.3.2 Policy context

Burkina Faso has demonstrated significant commitment to various international treaties and conventions. Indeed, the country has ratified several international and regional agreements that reaffirm: (i) their awareness of the important cultural, regulating, and provisioning as well as supporting functions that the forest ecosystem plays in the lives of many people; and (ii) that these resources are under significant pressure. However, the forest management at the local level has evolved over many generations. Community and participatory forest management traditions started many decades ago. Initially, farmers were excluded from the forest management process with the state having the sole authority to make decisions over forest resources. Farmers were eventually incorporated into the management process as a means of drawing on their now considered valuable local knowledge. The management of forest resources at the community level in its different forms has become widespread. There are many other examples of interventions, projects, programs, international organizations and institutions that have adopted similar community or participatory approaches to forestry. Burkina Faso has a great deal of experience in this area, especially in relation to rural forestry, participatory development of natural forests and agroforestry.

Local authorities have the right to decide the most effective method of managing their environmental resources based on local development plans. However, in practice, this transfer of authority, and the necessary financial resources (as pledged in the national legislation), has not yet taken place in Burkina Faso. Instead, the allocation of resources often operates through mechanisms such as tax collection from the exploitation of environmental resources, budget allocation from the state, or through joint and participatory management actions. Indeed, the law allows local authorities to create taxes that increase their income, as the financial resources of local authorities consist of their own revenues, budget allocations from the state and any other contributions (Law No. 055-2004/AN).

ARN is being implemented by farmers, land owners in rural areas. The implementation is often led by NGOs (e.g., newTree, Tiipaalga). Funding is primarily provided through international projects such as the Forest Investment Program (FIP). Half of the restoration initiatives have sourced at least part of their planting materials from the National Tree Seed Center which is a government-run seed conservation and production research center that offers a large range of native species and ensures that collection practices follow best standards.

4.3.3 Current land use and potential land-use competition

NGOs have played an important role in bringing awareness and sensibilisation of rural populations on this LMT in early 2000. In particular, the Swiss NGO newTree and its partner Tiipaalga introduced the ARN to Center and North Burkina Faso in 2003. Since then, the project allowed the creation of 351 ARN zones of around 3 ha each, equalling a total surface of 981 ha and the growth of 800,000 trees. Results of the project are regularly monitored through inventories of biomass and biodiversity. The main competition for ARN is agricultural land use and commercial forestry plantations that provide fast and higher returns than ARN zones.

4.3.4 Climate risks & sensitivities

The dry forests of Burkina Faso are negatively affected by rising temperatures, droughts, extreme rain events and bushfires. ARN spaces allow growing forests to be more resilient to the effects of climate, particularly by protecting them against bushfires.

4.3.5 Economic implications

ARN is cheaper than reforesting/afforesting practices (approximately half of the investment) that require extra costs for seed collection, nursery, planting and irrigating. Labour is the main cost associated with the implementation, see average ARN establishment and maintenance costs in Table . However, when fencing is applied, these financial gains are reduced (Shono, Chazdon, Bodin, Wilson, & Durst, 2020). According to the research of Belem et al. (2017) on the outcomes of the newTree approach in Burkina Faso, 20% of the yearly gross profit of the farmers come from the natural resources of the ARN. Moreover, they uncovered that 70% of the natural products of the ARN were self-consumed. They concluded that ARN played an important role in poverty alleviation in the country.

Table 3: Costs of ARN implementation based on literature review and available data from Americas, Asia and Africa (Shono, Chazdon, Bodin, Wilson, & Durst, 2020).

Cost category	Direct cost [USD]
Establishment cost / ha, year 1	20-579 (average: 257)
Annual maintenance and monitoring cost / ha, year 1-5	31-213
Annual maintenance and monitoring cost / ha, year 5-15	14-17

4.3.6 Co-benefits and trade-offs

Human-induced disturbances (fires, livestock grazing, unsustainable harvesting) are among the risks. The area should not be suitable for land uses that are economically more attractive.

On the long term, co-benefits of the LMT include restoration of soil fertility, increased availability of timber as well as non-timber forest products. Animal (e.g., pollinators) and vegetation biodiversity is also increased allowing the local populations to benefit from diverse indigenous plants and fruits for food and medicinal purposes (Belem, et al., 2017). Other environmental benefits include soil erosion control and improved water quality.

In addition, ARN is less labour-intensive, makes use of local knowledge and is a bottom-up approach that villagers usually apply on their own land. The species selected are these that best fit villagers' needs. This facilitates acceptance and sustainability of the technique.

As a trade-off, ARN zones have lower commercial values than tree plantations regarding timber and the growth is slower (Belem, et al., 2017).

4.3.7 Risks associated with scaling up

According to the FAO, the following factors are critical for the successful completion of an ARN project: clear land tenure, supportive policies, benefits accruing to local stakeholders, and technical expertise.

These apply to reforestation/afforestation projects as well. Moreover, more awareness and attention need to be brought to ARN which is currently still poorly understood, especially among policy makers who usually overlook it and favour tree planting.

As with the other LMTs, the lack of monitoring and mapping is the main research gap. Moreover, ARN fields are usually small and randomly localized and are for this reason challenging to spot. Using satellite imagery, ARN zones are easily confused with other types of tree-based land use which make their identification difficult. Hence, a more advanced monitoring technologies are required.

4.4 Reduced deforestation by promoting improved cook stoves and biodigesters

4.4.1 Introduction

The energy sector in Burkina Faso heavily relies on the use of fuelwood, charcoal and crop residues. The total primary energy supply is made up 80.5% biomass energy (Ruben, 2013). In addition to household's personal use for cooking and lighting, fuelwood contributes to Government's revenues (forest and community taxes related with fuelwood sales) and generates employment. This creates considerable pressure on timber resources and can trigger respiratory diseases to the population inhaling the biomass fuels. Improved Cooking Stoves (ICS) are a low-cost technology that has been promoted in Burkina Faso for more than a decade. It aims at improving biomass combustion efficiency and therefore save fuelwood (around 20-30%) while reducing indoor air pollution and greenhouse gas emissions. Biodigesters are on the other hand a clean technology that is more complex and more expensive. A biodigester converts organic waste into biogas (mixture of several gases, mainly consisting of methane) and fertilizer.

4.4.2 Policy context

The minister of Energy has exposed his vision on the national energy strategy: "By 2023, Burkina's energy sector, relying on endogenous resources and regional cooperation, ensures sustainable access to modern energy services and reinforces its driving role on sustainable development". Among the existing programs that have worked at promoting ICS and biodigesters, we can name:

- **The Foyers Améliorés au Burkina Faso (FAFASO)**
  The FAFASO is an ICS project established in 2005 by the Dutch Government and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The project's objective is to form a sustainable market for domestic and industrial ICS by providing training to whitesmith to produce ICS locally and through promotion campaigns.
- **The National Biodigesters Program (PNB-BF)**
  The PNB-BF dates back from 2010 and has since then facilitated the installation of biodigesters in households. In 2018, the program was considered to have saved 311 ha of forest and led to the sequestration of 17500 tons of CO_2 per year.

ICS and biodigesters are being used domestically by rural and urban populations but also industrially (e.g., dolo beer brewers). International funds are available such as ODA funding from the Dutch Government for PNB-BF. The Carbon Initiative for Development (CiDev) will purchase carbon credits generated by the biodigesters installed during the program's development and these funds will help the project to continue:

- disseminating information on the benefits of biodigesters for clean cooking and agricultural improvement,
- training masons on biodigester construction and conducting quality control measures. (https://ci-dev.org/programs/west-africa-biodigesters).

4.4.3 Current land use and potential land-use competition

Before 2005, ICS were poorly exploited in Burkina Faso. A significant adoption of the technology started with the FAFASO project with 107,000 stoves being sold for domestic use between 2005 and 2011 (Ruben, 2013). By 2030, the country's ambition is to allow the dissemination of another 540,000 ICS (Burkina Faso, 2015). Trends in biodigester use in Burkina Faso have also been increasing in the last decade. Only one biodigester was reported in 2009 against 4013 in 2014, with another 18200 biodigesters distributed between 2014 and 2018 (Burkina Faso, Ministère de l'Energie , 2018). In its national strategy document, Burkina Faso plans for an additional 40 000 biodigesters to be installed in households by 2022. As part of the INDC adaptation plan, Burkina Faso pledges to distribute a total of 75,000 biodigesters by 2030. Biogas adoption has been related to the availability of timber supply. In areas where fuelwood is abundant, biodigester appear less attractive to the local communities.

4.4.4 Climate risks & sensitivities

The climate sensitivity of the LMT is negligeable or non-existent.

4.4.5 Economic implications

The LMT has shown to be cost-effective and has direct and indirect financial and economic benefits. For instance, Burkina Faso has estimated in its INDC document that the plan to install ICS in 540,000 households by 2030 will have a ROI of 166% for the national economy and the plan of distributing 75,000 biodigesters will have a ROI of 104%. Indirectly, biodigesters are also economically advantageous through the application of compost allowing smart agriculture, see Table . Similarly, the IOB evaluation of the FAFASO project concluded that buying and using an ICS was profitable for households with the investment being amortised within 2.5 to 4 months thanks to firewood savings (1.42 euros saved monthly).

Table 4: Burkina Faso INDC adaptation actions on the dissemination of ICS and biodigester technology and estimated cost and effect by 2030 (Burkina Faso, 2015).

INDC adaptation projects	Investment cost [USD]	Tons of CO_2 saved / year	Cost [USD]/ tons of CO2 equ. /ha/year	ROI [%]
540,000 ICS	12,096,000	610,200	-	166

75,000 biodigesters for household	136,500,000	300,000	-	104
Compost from the biodigesters is used to fertilise 750,000 ha of cultivable land	52,500,000	1,500,000	$4.66667e^{-5}$	450

The direct economic implication for ICS and biodigester users is related to financial savings (firewood, kerosene, time savings). Looking at the broader picture, avoiding deforestation and land degradation by limiting the overharvesting of firewood allows to sustain the livelihood of the rural populations depending on non-timber forests products for their subsidence and for sale. Women being the main actors in the exploitation of non-timber forest products, this will enable them to maintain and strengthen their income.

4.4.6 Co-benefits and trade-offs

Environmentally speaking, ICS and biodigesters have the advantages of reducing the need to harvest timber and therefore avoid deforestation. In addition to that, biodigesters have several other benefits. A bioproduct of the biodigesters is a digestate which can be used as organic fertilizer and improve soil quality and crop productivity. A study made by the World Bank in Burkina Faso has shown that farmers applying the digestate on their crops increased their maize yield from 0.89 tons/ha to 2.54 tons/ha, their rice yield from 0.78 tons/ha to 4.00 tons/ha, and sorghum yield from 0.81 tons/ha to 1.44 tons/ha (Freeman & Seppala, 2019). Other environmental co-benefits are the decrease in GHG emissions from the incomplete combustion of biomass and from manure (methane).

Biodigesters also holds health benefits and especially women's health as women are usually the ones to cook. Bio-digesters adopters have reported fewer respiratory and eye problems that non-adopters in several countries of Africa. On the social aspects, both ICS and biodigesters reduce the burden of wood collection for women

An increasingly dry climate, water shortages, and significant soil degradation are core challenges for the agriculture sector. Water shortage is a main barrier for the functionality of biodigesters and thus to their adoption. However, a dry climate and water availability problems do not necessarily lead to a rejection of biodigesters. PNB-BF experience shows that the population in the country's dry regions (Sahel zone) were among the best clients of the program; due to the digestate, soil water sequestration capacity is improved, leading to higher crop yields (World Bank, 2019).

4.4.7 Risks associated with scaling up

There a several major barriers to the scaling up of this LMT. For the biodigesters, the main ones are the high investment cost of the installation and lack of technical skills required to construct and maintain the machine. Large scale implementation requires as well to have enough supplies of water and feedstock. A minimum of 3-4 cows is required if cow dung is used for instance, which is a limitation for smallholders. Consequently, biodigesters are said to be used in farms with higher income, socio-economic status and educational level. In overall, acceptability of the technology is a main barrier.

Projects that target the promotion and communication around the ICS and biodigesters are critical for their dissemination.

4.4.8 Research gaps

There is no identified research gap associated with this LMT.

4.5 Sustainable land management practices on agricultural land

4.5.1 Introduction

Over-farming, over-grazing and the increasing pressures of climate change are responsible for an important land degradation in the country. In the last decades, smallholders in Burkina Faso have implemented a set of sustainable agricultural techniques to effectively apply soil and water conservation techniques (SWC) on desertic and unfertile land:

Stone barriers, zai pits, half moons

Among the most common SWC practices to restore degraded land in Burkina Faso, we can name: zai pits, half-moons and permeable rock contour barriers (Lenhardt, Glennie, Ali, & Morin, 2014). Contour barriers consist of rocks tightly put next to each other around a field in order to trap water and avoid soil erosion during heavy rain events. Zai are planting pits aimed at rehabilitating soil by increasing termite activity, in turn increasing rainfall infiltration. Half-moons are other structures in semi-circular form that aim at retaining run-off for crop production. These practices are low-cost and can be combined into more complex systems.

Figure 5: Photographs of half-moon (left) and Zai (right) in Burkina Faso (Source: mcc.org).

Agroforestry parklands (AFP)

AFP are a widespread and traditional agroforestry practice in Burkina Faso that help restoring degraded land. They are dynamic systems where indigenous trees are planted and grow under protection on cropped/grazed land. The micro-climate created by the trees allow to increase the productivity of crops around/under the trees.

4.5.2 Policy context

Currently, there is no national policies that promotes SWC agricultural practices in Burkina Faso and no subsidies to support it (Neya, et al., 2020). It is however in the country's INDC ambitions to implement agroforestry and the SWC techniques listed in this document to reach 2030 mitigation and adaptation goals. The Forest Investment Program is a main framework for planning and implementing the necessary activities to reach success.

Farmers are adopting and applying these SWC and agroforestry techniques on their degraded farmland. Burkina Faso receives support from the AfDB and World Bank through the Forest Investment Program (FIP) and the Forest Carbon Partnership Facility (FCPF) to put in place a national REDD+ strategy to address the drivers of deforestation and forest degradation, including security of land tenure and management of agricultural-sylvicultural-pastoral systems.

4.5.3 Current land use and potential land-use competition

The state of land degradation and desertification in the 1970s and 1980s called for urgent restoration efforts. The Government turned to NGOs to propose a set of relevant SWC techniques and several initiatives were implemented with various success, see Table . SWC adoption increased considerably between 1993 and 2006, as seen in Figure 2. Adoption is more useful and widespread in regions where rainfall events are scarce.

Table 5: Most common SWC techniques in Burkina Faso and their implementation (Nyamekye, Thiel, Schönbrodt-Stitt, Zoungrana, & Amekudzi, 2018)

SWC	Year of implementation	Climatic zone
Half-moon	1958	Sahel and Sudan-Sahel
Zai	1980	Part of Sahel and part of Sudan-Sahel
Rock contour barriers	Late 1970s, early 1980s	Sahel, Sudan-Sahel,and Sudan-Guinea
Agroforestry	1970	Sahel, Sudan-Sahel,and Sudan-Guinea

Today, these techniques still play an important role in the Burkinabe Government to boost CO_2 intake and restore land productivity. NDC land-based adaptation plans include fertility restoration and maintenance for 1,575 million ha of degraded land through various SWC techniques by 2030. This includes among others, the establishment of 225,000 ha of zai, 525,000 of zai combined with stone barriers, 675,000 ha of plant covered stone barriers, 650,000 ha of zai combined with stone barriers and ARN, and finally 150,000 ha of half-moons (Burkina Faso, 2015). The suitable agroforestry area has been estimated to be over 10 milllion ha representing 38% of the country side (IFN 2, 2015).

Farmers do not always have the incentives to adopt these measures and will instead apply more standard cropping techniques that require less efforts and investments. Moreover, it has been widely reported that trees and crops also may compete for resources above ground (light, heat, water) and below ground (nutrients, water). Selection of the right woody (trees and shrubs) and agricultural crop components is important (Bayala, Sanou, Teklehaimanot, Kalinganire, & Ouedraogo, 2014)

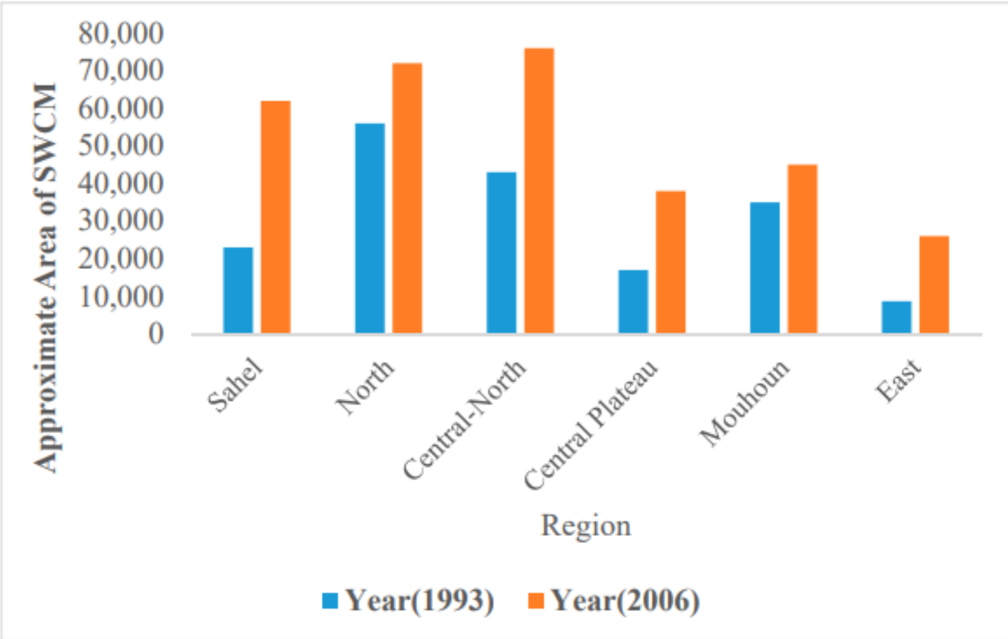

Figure 2: Surface of land that adopted SWC techniques per region of Burkina Faso (Nyamekye, Thiel, Schönbrodt-Stitt, Zoungrana, & Amekudzi, 2018).

4.5.4 Climate risks & sensitivities

AGP are vulnerable to drought and extreme temperatures. Heavy rain may destroy SWC measures such as half moons.

4.5.5 Economic implications

Although agroforestry has benefits for climate mitigation, it is not very profitable at the farm level for smallholders. The carbon price generally is not able to compensate farmers' efforts (the trade-offs). Appropriate incentives are needed to enable farmers to adopt it. The carbon price should be at least 4 US$ per tCO_2 to enable smallholders to adopt and promote agroforestry parklands (Neya, et al., 2020).

Land tenure plays an important role as often farmers are not the real owners of the land, and the absence of long-term ownership affects the adaption of SWCM. Table 6 below lists the expected cost, profitability and climatic impact of the SWC techniques included in the INDC adaptation plan.

Table 6: Burkina Faso INDC adaptation actions on the dissemination of SWC practices and estimated cost and effect by 2030 (Burkina Faso, 2015).

INDC adaptation projects	Investment cost [USD]	Tons of CO_2 saved / year	Cost [USD]/ tons of CO_2 equ. /ha/year	ROI [%]
225,000 ha of zai	94,500,000	666,000	0.00045045	67
525,000 ha of combined zai and stone barriers	367,500,000	1,554,000	0.000182182	45
675,000 ha of plant covered stone barriers	245,700,000	1,998,000	0.001813063	31
150,000 ha of combined stone barriers, zai and ARN	120,750,000	444,000	0.000945946	39
150,000 ha of half-moons (with addition of manure)	63,000,000	444,000	0.00045045	100

4.5.6 Co-benefits and trade-offs

SWC techniques such as rock barriers have positive impacts on topsoil thickness and nutrient holding capacity by avoiding soil erosion by water. This is linked to improved water infiltration with increased in groundwater levels in many villages (Nyamekye, Thiel, Schönbrodt-Stitt, Zoungrana, & Amekudzi, 2018). On top of the climate benefits through rehabilitated land and related decreased pressure on neighbouring forests, SWC techniques have been shown to increase crop yield and therefore have an impact on food security and rural poverty. In the past, rural poverty was reduced by 50% between 1985 and 1996.

Soil and water conservation measures reduce streamflow and erosion which may dry up wells during the dry season. Also, many SWC initiatives focus on the soil rehabilitation of agricultural lands and pay less attention to the spatial dimensions of soil erosion and the conservation of natural vegetation.

4.5.7 Risks associated with scaling up

As the other LMT listed in this document, sustainable land management practices on cropland succeed when land ownership is ensured. The SWC techniques mentioned here are to be promoted in geographic regions facing water scarcity. In regions with ample rainfall, they are less adapted as they can create waterlogging (Nyamekye, Thiel, Schönbrodt-Stitt, Zoungrana, & Amekudzi, 2018).

4.5.8 Research gaps

The current extent of AFP and other SWC techniques in Burkina Faso is not well documented, and neither is their precise evolution through the years. Bayala et al., (2014) stated that there is a need for a more comprehensive analysis of the multiple benefits and services provided by parkland trees.

5. Conclusions

Burkina Faso is landlocked between 9° and 15° N, and 6° W and 3° E. It has a total landmass of 274,000 km² (FAO 2011) and covers three major climatic zones: Sahelian, Sudanian, and Sudanian-Sahelian. The population growth rate is 3.5%, which is considered one of the highest in Africa. Eighty-five percent of the population is rural and dependent on agriculture and livestock. The center and north of the country have low vegetation cover. Both regions have similar levels of rainfall, soil, and vegetation types. The most wooded areas are in the west and center west of the country. Estimates of Burkina Faso's total forest cover vary between sources, many of which use different methods of assessment. However, recent FAO statistics (FAO 2011) reported 5,649,000 ha of forest cover in Burkina Faso, accounting for 21% of the total land area, and 'other wooded lands' accounting for 18%. Shrublands represent the most common type of land use, followed by fallow and agroforestry areas, and wooded savannas.

In Burkina Faso, the land is used for urban development, agriculture, grazing, mining, forest management, and exploitation. Pastoralism is predominant in the north but occurs throughout. Forest-based livelihood activities are concentrated in the Sudanian-type ecozones. The degradation of ecosystems in Burkina Faso has been consistent, often explained by climatic deterioration and increasing demographic pressure on natural resources. Forest loss primarily occurs as a result of uncontrolled bushfires, fuelwood harvest, encroachment into forest areas for agricultural production (i.e. for crops and livestock), and mining expansion.

We conducted stakeholder engagements in the country with a help of a local consultant. Stakeholders included farmers, researchers, NGOs, and representatives from government agencies. These engagements helped us to select the most relevant LMTs in terms of carbon sequestration potential and co-benefits on the local, national, and regional levels. These LMTs are part of the country's commitments for 2030 and mainly aim at planting trees, restoring degraded land, and reducing pressures on forests: 1) Reforestation, afforestation, and forests classification; 2) Sustainable land management practices on forest land with a focus on Assisted Natural Regeneration (ARN); 3) Reduced deforestation by promoting improved cookstoves and biodigesters; and 4) Sustainable land management practices on agricultural land with focus on agroforestry parklands and soil fertility restoration such as stone barriers, Zai pits, half-moons.

Burkina Faso offers a unique opportunity for a triple win of mitigation, adaptation, and poverty alleviation. Enhancing the management of forest resources will strengthen the adaptation potential against adverse impacts from climate change and will create positive spillover effects for poverty alleviation, such as increased forest production and enhanced agricultural productivity (e.g. agroforestry). However, these multiple co-benefits cannot be achieved without a transformational process toward a landscape approach of integrated natural resource management. Such an approach would analyze the best way to conciliate local development with the limitation of the drivers of deforestation and forest/woodland degradation in different ecosystems.

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ANNEX III

OVERVIEW OF INPUT TABLES FOR SIMULATION MODELLING PER COUNTRY

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8. Burkina Faso

8.1. Qualitative storylines by identifying measures and actions from interviews for each LMT scenario

Burkina Faso LMT 1: Agroforestry

	1. Wishes of the future for the LMT: include timing	2. How to achieve the wishes • Who pays? • Who implements?	3. Target/Actions • Policies, strategies, projects
Scenario 1: "Max growth" Stakeholder representations:	• Agroforestry increased by 70% by 2030 (1.9 million hectares) and by 150% by 2050 (4 million hectares)	• it can involve a combination of government, international donors, private sector actors, community-based organizations, farmers, extension agents, non-governmental organizations, and other stakeholders.	• Develop and implement policy and institutional frameworks that support agroforestry. • Provide financing mechanisms such as grants, subsidies, loans, and insurance to enable stakeholders to invest in agroforestry practices. • Loosening strictness of permanence for CO_2 certification --> each t CO_2 sequestered is positive • Provide technical assistance, capacity building, and research and development to enhance the knowledge

			and skills of stakeholders in agroforestry practices. • Involve local communities in the design, implementation, monitoring, and evaluation of agroforestry practices to ensure their ownership, sustainability, and effectiveness.
Scenario 2: "Slow growth" Stakeholder representations:	• Agroforestry increased by 20% by 2030 (0.5 million hectares) and by 80% by 2050 (2 million hectares)	• it can involve a combination of government, international donors, private sector actors, community-based organizations, farmers, extension agents, non-governmental organizations, and other stakeholders	• Provide financing mechanisms such as grants, subsidies, loans, and insurance to enable stakeholders to invest in agroforestry • Support implementations led by farmers, extension agents, NGOs, and other stakeholders, with support from the government and other partners.
Scenario 3: "Stay as current"	• Agroforestry stays at 13% (2.7 million hectares of Burkina Faso's land area	• No new resources directed	• No additional policies (e.g. SH workshop SBV, no additional money, not attractive to farmers)

Burkina Faso LMT 2: Cropland Management

	1. What are the wishes of the future for the LMT: include timing	2. How to achieve the wishes • How much does it cost? • Who pays for the cost? • Who implements?	3. Actions • policies, strategies, projects
Scenario 1: "Max growth" Stakeholder representations:	• By 2050, almost all farm areas are following best practices in managing their land.	• significant investment from the government, private sector, and development partners. The specific cost of these interventions would depend on the technologies and practices used, but they would likely require long-term investment and sustained commitment to achieving sustainable results.	• National Agricultural Investment Plan (NAIP) • National Rural Land Use Plan (PNFDR) • Agricultural Value Chains Development Project (AVCDP) • Sustainable Land Management Project (PROGRES)
Scenario 2: "Slow growth" Stakeholder representations:	• By 2050, 40% of the arable land under organic agriculture	• Farmers and NGO's only driven project at local scale	• Awareness campaigns of environmental co-benefits (and health concerns) • Building resilience to climate change: To achieve that, farmers would need access to drought-resistant crop varieties, soil conservation practices, and agroforestry systems.

Scenario 3: " Stay as current"	• By 2050, 15% of the arable land under organic agriculture	• No new resources directed	• No additional policies (e.g. SH workshop, no additional money, not attractive to farmers)

Burkina Faso LMT 3: Forest Management

	4. What are the wishes of the future for the LMT: include timing	5. How to achieve the wishes • How much does it cost? • Who pays for the cost? • Who implements?	6. Actions • policies, strategies, projects
Scenario 1: "Max growth" Stakeholder representations:	• By 2050, all forest areas are protected and managed in a sustainable way.	• Funding could come from a variety of sources, including domestic and international sources. Domestically, the government of Burkina Faso could allocate funds from its national budget for forest management activities. Internationally, funding could come from bilateral and multilateral development partners, as well as private sector investment.	• This could involve developing policies and regulations to promote sustainable forest management practices, as well as engaging with the private sector to encourage sustainable supply chains and investments in sustainable forest management. • Expansion of protected areas: This could involve the creation of new national parks and reserves, as well as the expansion of existing protected areas. • Strengthening law enforcement: This could

			include training and equipping forest rangers and other law enforcement personnel, as well as improving monitoring and enforcement activities to combat illegal logging.
Scenario 2: "Slow growth" Stakeholder representations:	• By 2050, 50% of the forest areas are protected and managed in a sustainable way.	• Funding could come from similar sources as the Max Implementation Scenario, including domestic and international sources but with much lower capacity and scale.	• Incremental strengthening of law enforcement: This could involve a phased approach to training and equipping forest rangers and other law enforcement personnel, as well as improving monitoring and enforcement activities. • Gradual promotion of sustainable forest management: This could involve a phased approach to developing policies and regulations to promote sustainable forest management practices, as well as engaging with the private sector to encourage sustainable supply chains and investments in sustainable forest management.

			• Gradual promotion of sustainable forest management: This could involve a phased approach to developing policies and regulations to promote sustainable forest management practices, as well as engaging with the private sector to encourage sustainable supply chains and investments in sustainable forest management.
Scenario 3: " Stay as current"	• By 2050, 12% of the forest areas are protected and managed in a sustainable way.	• No new resources directed	• Maintaining current protected areas: This would involve continuing to manage existing national parks and reserves without expanding them. • Maintaining current law enforcement efforts: This would involve continuing current monitoring and enforcement activities without strengthening them. • Maintaining current forest management practices: This would involve continuing to manage forests according to

			current policies and regulations without promoting sustainable forest management practices.

Burkina Faso LMT 4: Afforestation and Reforestation

	7. What are the wishes of the future for the LMT: include timing	8. How to achieve the wishes • How much does it cost? • Who pays for the cost? • Who implements?	9. Actions • policies, strategies, projects
Scenario 1: "Max growth" Stakeholder representations:	• By 2030, the forest cover in Burkina Faso would increase by approximately 5%. • By 2050, the forest cover in Burkina Faso would increase by approximately 15%. • The country would have restored 5 million hectares of degraded land by 2030. • The country would have planted over 1 billion trees by 2050.	• The cost of implementing this scenario would depend on various factors, including the extent of afforestation and reforestation efforts, the types of interventions used, and the level of community engagement. According to the World Bank, the cost of restoring one hectare of degraded land in Burkina Faso ranges from $250 to $1,500, depending on the level of intervention. Therefore, restoring 5 million hectares of degraded land by 2030	• Developing and implementing policies that support afforestation and reforestation, such as forest restoration programs, sustainable land management practices, and community-based forest management initiatives. • Mobilizing resources and funding from both national and international sources to support afforestation and reforestation efforts. • Strengthening institutional capacity and coordination among relevant government

		could cost between $1.25 billion and $7.5 billion. • The cost of implementing this scenario could be paid for by a combination of sources, including the government, international donors, and the private sector. The government could allocate resources from the national budget to support afforestation and reforestation efforts, while international donors could provide funding through programs such as the Green Climate Fund or the World Bank's Forest Carbon Partnership Facility. The private sector could also contribute through corporate social responsibility initiatives or investments in sustainable forest management.	agencies, civil society organizations, and local communities. • Promoting awareness and education on the importance of afforestation and reforestation for ecosystem services and livelihoods.
Scenario 2: "Slow growth" Stakeholder representations:	• By 2030, the forest cover in Burkina Faso would increase by approximately 2%.	• The cost of implementing this scenario would be lower than Scenario 1. For example, restoring 2 million hectares of degraded land	• Prioritizing afforestation and reforestation efforts in areas where the benefits are highest, such as areas with high biodiversity, ecosystem

	• By 2050, the forest cover in Burkina Faso would increase by approximately 10%. • The country would have restored 2 million hectares of degraded land by 2030. • The country would have planted over 100 million trees by 2050.	by 2030 could cost between $0.5 billion and $3 billion • The cost could be shared among various stakeholders, including the government, international donors, private sector partners, and local communities.	services, and/or high vulnerability to climate change. • Fostering partnerships between the government, private sector partners, civil society organizations, and local communities to mobilize resources and expertise for forest restoration efforts. • Providing incentives for sustainable land use practices that promote both food security and forest restoration. • Strengthening institutional capacity and governance for effective forest management.
Scenario 3: " Stay as current"	• By 2030, the forest cover in Burkina Faso would remain at approximately 14%. • By 2050, the forest cover in Burkina Faso would remain at approximately 14%. • The country would not have restored any degraded land by 2030.	• No new resources directed	• The country would not implement any new efforts towards afforestation and reforestation. • The country would not have restored any degraded land by 2030. • The country would not have planted any new trees by 2050.

	• The country would not have planted any new trees by 2050.		

8.2. Quantitative storylines: pace of implementation for each LMT

Table 2: Quantitative trends/pace of implementation of LMT options

	Current situation (baseline)	SCEN-" Max growth " SH perspective:		SCEN-" Slow growth" SH perspective:		SCEN-" stay as current" SH perspective	
Year	Now (provide sources)	2030 (change relative to the current situation) (provide sources)	2050 (change relative to the current situation) (provide sources)	2030 (change relative to the current situation) (provide sources)	2050 (change relative to the current situation) (provide sources)	2030 (change relative to the current situation) (provide sources)	2050 (change relative to the current situation) (provide sources)
LMT 1: Agroforestry	13%	70% increase	150% increase	20% increase	70% increase	0%	0%
LMT 2: Cropland management	15%	50% of arable land	100% arable land	20% of arable land	40% of arable land	0%	0%
LMT 3: Forest Management	12%	30% of forest areas	100% of forest areas	20% of forest areas	50% of forest areas	0%	0%
LMT 4: Afforestation and Reforestation	14%	Increase by 5%	Increase by 15%	Increase by 2%	Increase by 10%	0%	0%