APPENDIX 4: PILOT 1: MOUNTAIN HAZELNUT VENTURES

1.Executive summary

As part of the "Land Degradation Neutrality Fund (LDNF) Impact Monitoring Methodology" developed by Conservation International and OpenGeoHub two pilot studies were completed. This document presents the pilot study for the Mountain Hazelnut Ventures, a fully traceable hazelnut production business in Bhutan. The pilot includes project baseline for the three LDN indicators, changes in land cover, land productivity and soil organic Carbon, which also includes recommendations on how to monitor the indicators over the project lifespan, and an appendix presenting an assessment of potential impact of project activities on the three LDN indicators which is intended to inform the implementation of the monitoring plan.

The Mountain Hazelnut Ventures LDN baseline found that:

- Land productivity: 7.8 % of the investment area is currently identified as degraded compared to 5.9 % within the larger investment landscape
- Land cover: 72.2 % of the investment area is currently classified as grassland or cropland, while those covers in the larger investment landscape represent only 17.4 %. The investment landscape, on the other hand, is dominated by tree covered areas (81.2 %) compared to only 25.3 % within the investment area.
- Soil organic carbon: Baseline SOC content within the first 30 cm of the soil was 73.9 tons C/ha in fallow sites, compared to 85.9 tons C/ha in hazelnut orchards with at least 6 years of age.

The proposed monitoring plan following the LDNF Impact Monitoring Methodology is:

- Land productivity: Wall to wall annual assessment using remote sensing data
- Land cover: Wal to wall repeated measures of land cover change every four years relying in land cover maps at 30 m spatial resolution produced by the national government. If those maps were not available within the required frequency, similar maps could be produced in house using freely available imagery. Very high spatial resolution data could be useful for producing land cover maps areas of particular interest to the company or the LDNF. fully traceable hazelnut production
- Soil organic carbon: Initial and final SOC measurements with in the same representative area used for the baseline and following the same cluster design. Annually, hazelnut production measures can be used to assess changes in productive capacity of the soil and impact of ongoing agricultural practices.

2.Mountain Hazelnut Ventures[6]

Mountain Hazelnuts (MHV) was founded in 2009 as Bhutan's first 100% foreign direct investment with a mission of creating a profitable business that provides long-term income for vulnerable rural communities by planting 10 million hazelnut trees on fallow and degraded mountain slopes. A Memorandum of Understanding (MoU) with the Bhutanese government allows farmers without land to participate in the project by leasing land from the Government. MHV has since established fully traceable hazelnut production, boosting the country's exports and providing income generation opportunities through direct employment, extending to its supply chain as well as hazelnut growers who sell their harvests to the Company.

To date, Mountain Hazelnuts has integrated 12,091 farming households in its value chain. Growers and community groups (e.g., nunneries) are provided with hazelnut trees and inputs, plus training on best agricultural practices, followed by regular extension visits. Each full-grown tree can yield 4 to 6 kilos of nuts. Mountain Hazelnuts buys all harvested nuts according to a guaranteed price structure that removes market risk for the growers and ensures a profitable crop. With the typical rural household in Bhutan earning a cash income of less than $500 a year, these incremental earnings based solely on the sale of the hazelnuts will help farmers dramatically boost their incomes. By improving the lives of these farmers MHV is also hoping to stem the crippling flow of younger Bhutanese villagers migrating to urban areas.

In addition to integrating more than 5,000 women farmers as suppliers of hazelnuts, Mountain Hazelnuts also directly employs 261 Bhutanese women from the rural communities it operates in and provides training and support for their health and personal finance. Mountain Hazelnuts takes a holistic approach to address household income generation, community development, cultural preservation, local ecosystems, and global climate change.

3.Defining the area of interest

Mountain Hazelnut Ventures works to date with 10,440 small farmers distributed throughout the country of Bhutan (Figure 1). Each of those 10,440 farmers represent an **investment site** (mean =0.46 ha, median = 0.40 ha, standard deviation = 0.45 ha), as defined in the LDNF Impact Monitoring Methodology. The aggregation of all those sites represent the full area of direct intervention the project will have in the region, referred to as the **investment area**. To better understand the context in which these activities will take place, and to compare the baseline conditions of the investment area to similar areas in the surrounding region, an investment landscape was defined for this project. Considering the highly heterogenous conditions of this

[6] Verbatim from: IFC & GASF. 2016. Bhutan: Blending Happiness and Hazelnuts with Finance. https://www.gafspfund.org/projects/blending-happiness-hazelnuts-bhutan

mountainous region, we defined the **investment landscape** for this project as all land within a 2 km buffer of the investment area (Figure 1).

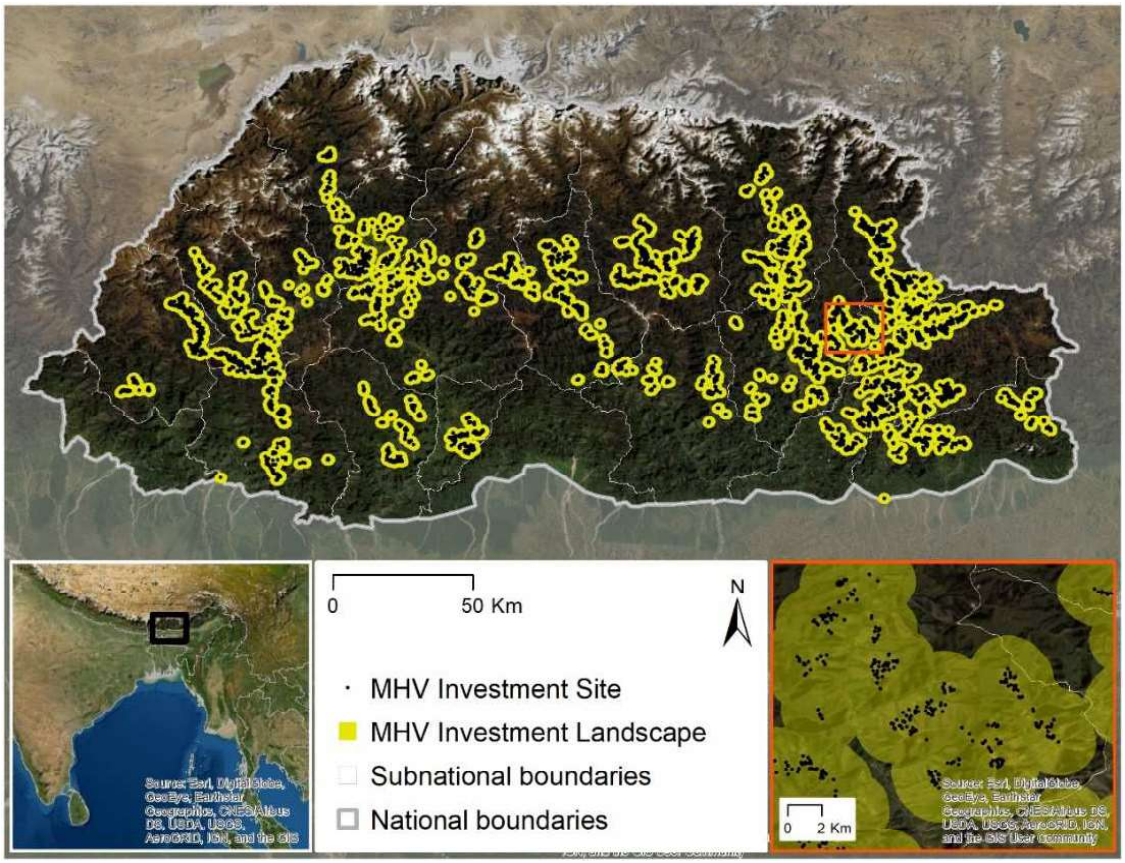

Figure 1: Mountain Hazelnut Ventures works to date in over 10,000 individual investment sites (black dots on the map). The investment area is the aggregate of all those sites. The investment landscape, in this case, has been defined as the area within a 2 km buffer around the investment area. Box on the lower right section of the figure presents a closer look to the distribution of sites and the surrounding landscape in South Eastern Bhutan.

4.The LDNF MHV project baseline

Projects part of the LDNF portfolio need to determine baseline conditions for each of the three indicators of land degradation (changes in primary productivity, land cover, and soil organic C), and monitor progress through the project lifespan. The LDNF Impact Monitoring Methodology provides guidance on how to complete baselines and set up the monitoring framework. In the sections below we present the baselines for the MHV project broken up by indicator.

4.1.Land productivity

Land productivity is the biological productive capacity of the land, the source of all food, fiber and fuel that sustains humans. Following the LDNF Impact Monitoring Methodology, it is recommended that the normalized difference vegetation index (NDVI) be used as an indicator of productivity, as it is well-correlated with actual changes in productivity based on measurement on the ground, and as there is a long-term record available to allow comparison of changes in NDVI in a particular year with how NDVI has changed in the past. Given the combination of small median size investment sites (0.40 ha) and large investment landscape (7,557.8 km^2), the recommended datasets for monitoring productivity would be at a resolution of ~30 m. However, presently only 250 m products are available for time series analysis as the ones needed for assessing productivity. For that reason, we computed productivity baselines using MODIS 250 m resolution data processed as recommended in the LDNF Impact Monitoring Methodology. For this baseline, we used Trends.Earth to compute the 5-class productivity indicator for the recommended most recent 15-year period 2005-2019 (Figure 2). The 5-class productivity integrates three sub indicators: trajectory, performance, and state.

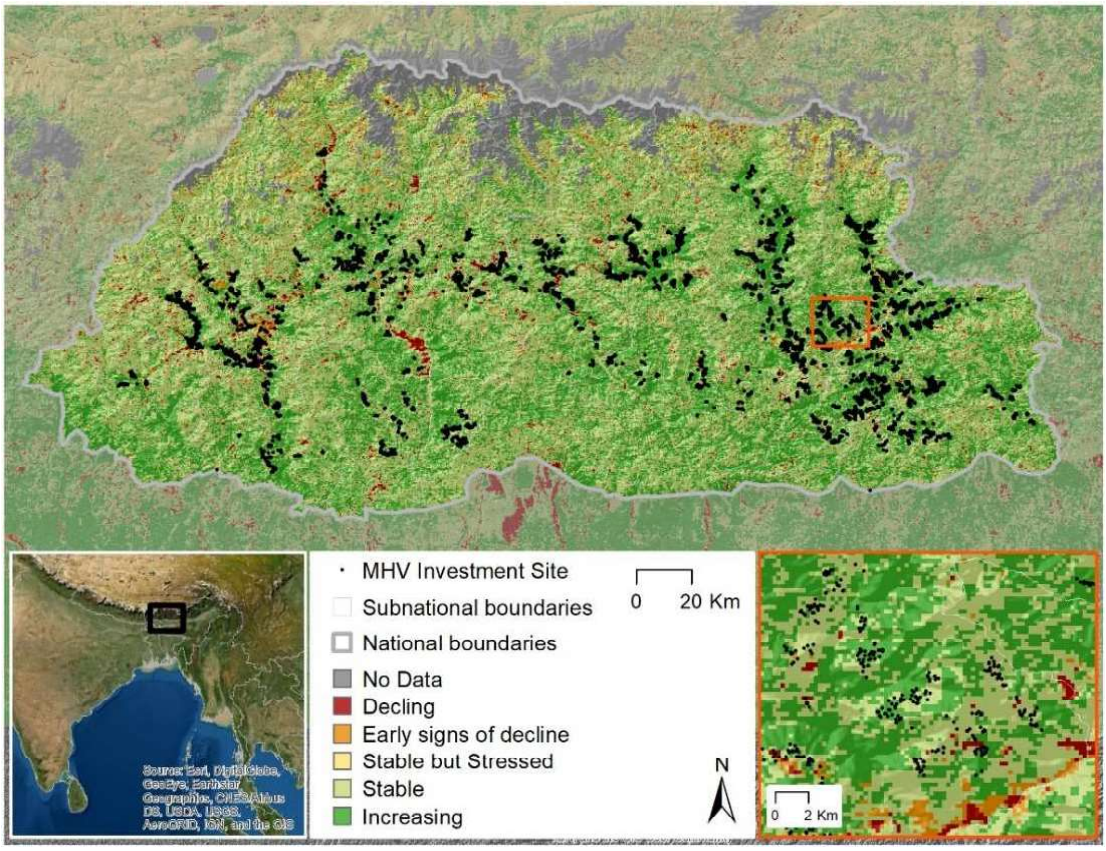

Figure 2: Productivity baseline map for the Mountain Hazelnut Ventures investments in Bhutan.

Overall, the investment area presents a baseline degradation level of 7.8 %, compared to 5.9 % degradation during the 2005-2019 period for the broader investment landscape. (table 1).

Productivity class	Investment Area	Investment Landscape
Declining	5.5 %	3.5 %
Early signs of decline	2.3 %	2.4 %
Stable but stressed	0 %	0 %
Stable	45.9 %	44.2 %
Increasing	46.3 %	49.9%
% Degraded	**7.8 %**	**5.9 %**

Table 1: Productivity baseline for the Mountain Hazelnut Ventures Investment Area and Landscape computed for the period 2005-2019.

Monitoring recommendations for productivity

Of the three LDN indicators, productivity if the most responsive to changes in land management and cover and any other condition which affects the productivity of the vegetative cover. For that reason, land productivity should be monitored annually to the LDNF following guidance from the LDNF Impact Monitoring Methodology. Through annual assessments of changes in land productivity, MHC and the LDNF will be able to monitor the impact of the investments on land degradation and adapt accordingly in order to maximize the contributions of the project towards LDN locally and at the national scale.

4.2.Land cover

Through the assessment of changes in land cover, major transitions in system structure and configuration can be monitored over time. It is critical to use a land cover product which aligns with the size and spatial distribution of the interventions being monitored, to have confidence in the reliability and usefulness of the results. The Government of Bhutan regularly produces land cover maps at 30 m resolution[7] which are used for national level reporting of LDN, among many other uses. In the case of the MHV project, the combination of small median size investment sites (0.40 ha) and large investment landscape (7,557.8 km^2), the use of a wall to wall maps at 30 m resolution was deemed appropriate for the baseline. Given resource availability, very high spatial resolution images in some focus areas could have been used if necessary, but based on the quality and coverage of the national level product, and the advantage of coordinating national and project level reporting needs.. Using the national land cover map from 2016 we developed the land cover baseline assessment for the investment area and landscape (Figure 3). The original

[7] FRMD, 2017, Land Use and Land Cover of Bhutan 2016, Maps and Statistics. Forest Resources and Management Division, Department of Forests & Park Services, Ministry of Agriculture and Forests, Thimphu, Bhutan. ISBN: 978-99936-743-2-0

land cover class scheme was aggregated to the 7 UNCCD recommended land cover classes: tree covered, grassland, cropland, bare, artificial, wetland, and water (Figure 3), and then summarized for the investment area and investment landscape (table 1).

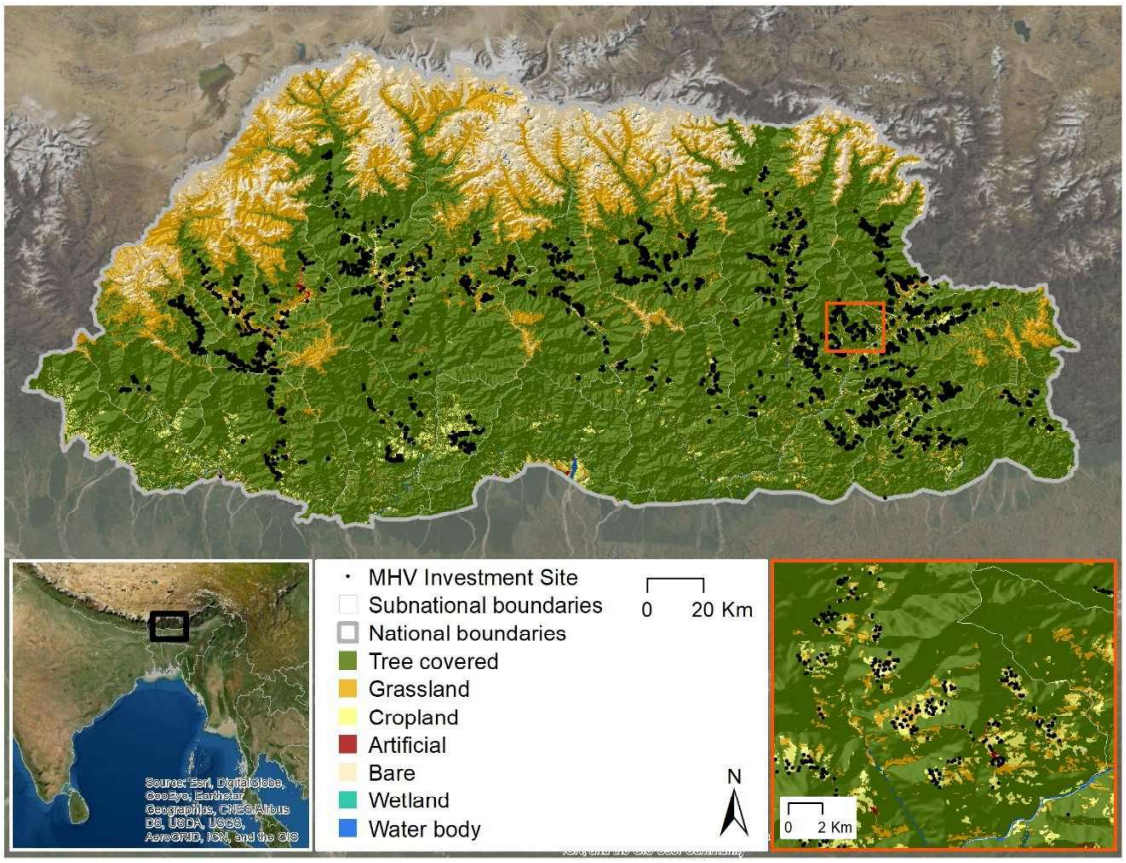

Figure 3: Land cover baseline map for the Mountain Hazelnut Ventures investments in Bhutan. Land cover data provided the Government of Bhutan (Land use and land cover of Bhutan, 2016) aggregated to the 7 UNCCD recommended land cover classes.

The baseline land cover distribution for the assessed area shows a dominance of cropland in the investment area (51.1%), while the overall landscape is dominated by trees (81.2 %). Combined croplands and grasslands represent 72.2% of the investment area as compared to only 17.4 % in the investment landscape. These results align with the objective of the project, which is to convert former agricultural lands not actively used to hazelnut orchards.

Land cover	Investment Area	Investment Landscape
Tree covered	25.3 %	81.2 %
Grassland	21.1 %	9.6 %

Cropland	51.1 %	7.8 %
Wetland	0.0 %	0.0 %
Artificial	2.3 %	0.7 %
Bare	0.0 %	0.2 %
Water body	0.1 %	0.6 %

Table 2: Productivity baseline for the Mountain Hazelnut Ventures Investment Area and Landscape computed for the period 2005-2019.

Monitoring recommendations for land cover

Changes in land cover tend to be slower than changes in primary productivity, for that reason, land cover is expected to be monitored and reported to the LDNF every 4 years at minimum. Given the track record of the national government in producing country wide land cover maps on a regular basis, it would seem appropriate to continue using those maps for reporting to the LDNF. Given resource availability and specific interest from the company or the Fund, very high spatial resolution images in some focus areas could provide useful insights and could be added to the monitoring plan and reports.

4.3.Soil organic carbon

Monitoring change in soil carbon due to project interventions requires the project proponent to consider several different decision points related to SOC and overall LDN project achievement. Recent guidance prepared by the Science-Policy Interface of the UNCCD can be applied to project descriptions to obtain guidance regarding investment into SOC assessment for LDN. The LDNF Impact Monitoring Methodology provides guidance on how to determine the appropriate monitoring in indicator depending on project objectives. Given the multi-purpose nature of the interventions being proposed by MHV, this project can be categorized as an agroforestry type of intervention. Agroforestry projects in the context of LDN are required to monitor SOC, through a combination of initial and final SOC assessments (either through field data collection or modeling) with production statistics as intermediate proxy variables for soil condition.

For this baseline, following guidance from MHV, the baseline sample area was identified in the eastern region of the investment landscape. This area representing 13.9 % of the investment landscape has the larger longer history in company operation and is centered around the company headquarters providing logistics, financial, and methodological advantages. During January 2020 2019, fieldwork was completed in this region (Figure 4). The main objective of the field work was to collect soil samples to produce the SOC baseline. Given the scale of the project and the significant landscape heterogeneity encompassed by that (due to the mountainous relief and quickly changing aspect), a clustered sampling design was implemented. Each cluster was defined in this case as a combination of fallow lands and hazelnut orchards with between 6 or 7

years since establishment, minimizing the variability in environmental factors which could contribute to the differences found in the response variables. Such a sampling design allows for achieving two main objectives: 1) completing the baseline SOC assessment (presented in this section), and 2) Applying a space-for-time substitution, to increase our understanding on the potential impact of the proposed interventions in SOC (presented in section 5).

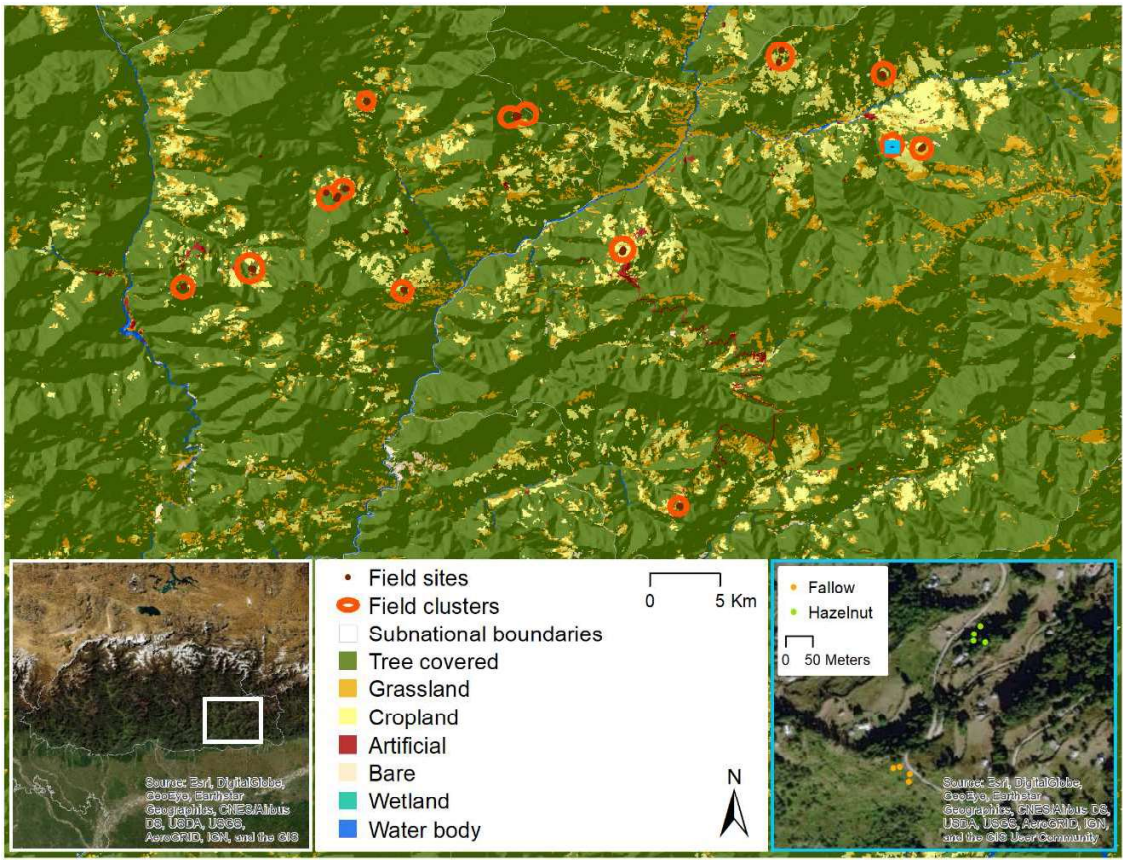

Figure 4*: Sampling design for the soil organic carbon baseline of* Mountain Hazelnut Ventures *in Bhutan. Land cover data provided the Government of Bhutan (Land use and land cover of Bhutan, 2016)*

During January 2020, fieldwork was completed in the south east region of the country of Bhutan, collected soil samples to 30 cm depth (4 samples per land cover and cluster, Figure 5). A total of 15 clusters were surveyed and within each cluster four soil samples were collected per fallow and orchard site (total 124 soil samples, see supplement material for details on protocol for soil sample collection and processing). Soil samples were collected with an auger to determine organic C concentration and bulk density for SOC stock estimations (see field guide for details

Figure 5. Field work photographs showing typical conditions in a fallow site (top left), seven-year-old hazelnut orchard (top right), soil sample (bottom left) and experimental crafting on native hazelnut varieties (bottom right).

on data collection). Soil samples were processed at the National Soil Services Center of Bhutan. In each point, coordinates were recorded, and history of use documented (current and before establishment of the orchard).

Soils are inherently spatially very variable, and the cluster design tries to minimize that variability to detect the significant differences. A two-way analysis of variance was used to assess the significance on the mean differences between the two interventions and controlling by the variability among clusters. Carbon content is very variable in the region, as can be observed

by the high vertical spread in Figure 9. Mean SOC stocks were higher on average in hazelnut orchars (85.9 tons C/ha) than fallow agricultural sites (73.9 tons C/ha), and the differences were statistically significant (p-value < 0.01).

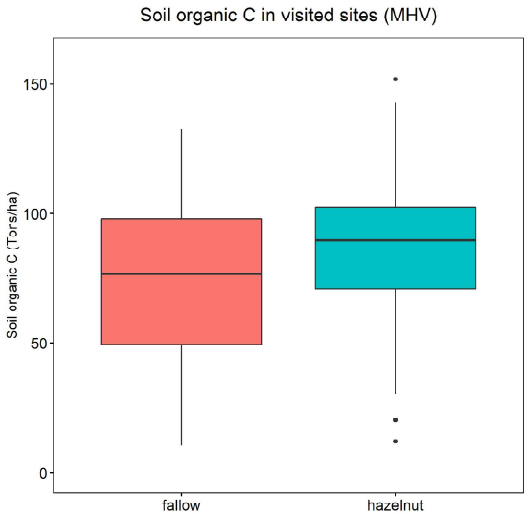

Figure 6. Mean SOC stocks in hazelnut orchards (85.9 tons/ha) and in in nearby fallow plots (73.9 tons/ha). Differences were significant to p-value < 0.01).

Monitoring recommendations for SOC

Soil organic carbon is, of the three LDN indicators, the most challenging to measure as EO data can only be of assistance, since SOC can not be directly measured from remotely sensed data. SOC is a slow changing variable, meaning that a long period needs to occur in order to detect significant changes in its magnitude after some type of intervention, such as the establishment of an agroforestry system. Moreover, field measurements are logistically challenging and require a significant resource. For that reason, the LDNF Impact Monitoring Methodology requires SOC to be measured (either with field data or modeled), at the beginning and end of the project, and using production measures (e.g. tons of hazelnuts produced per unit and area and time) as an intermediary proxy for understanding the changes in soil health to inform adaptive management measures which could be required in order to achieve LDN objectives.

5.Supplement I: Potential contributions to LDN

The cluster design implemented to produce the baseline for soil organic carbon, allowed us to produce some preliminary analysis on the potential contributions of the activities to be implemented as part of the Mountain Hazelnut Ventures project. Analysis presented in this

appendix are not required as part of the LDNF Impact Monitoring Methodology, but are recommended, since the insights obtained can be useful at designing a locally relevant monitoring plan.

5.1.Land productivity

To date, MODIS remote sensing data is the only available NDVI product with a time series record dense enough to produce robust land productivity baselines over a 15-year period. However, Landsat and Sentinel harmonized collections are actively being developed, and will be made available to the public within a years' time. This harmonized collection provides the spatial resolution of Landsat and Sentinel products, but with a much higher temporal frequency than each of the original products[8]. Having high spatial and temporal frequency is key for evaluating interventions with a small spatial footprint and which require the evaluation over the course of the year, and not just at one point in time. The Normalized Difference Vegetation Index (NDVI) from a sample Harmonized Landsat and Sentinel surface reflectance product was compute, and the annual integral for the years 2017 and 2018 were derived following SDG 15.3 guidance (Trends.Earth, 2018). Annual NDVI integral values were extracted for the 124 visited locations and analyzed for each year using a two-way analysis of variance[9].

For the assessment of potential impact of MHV interventions on productivity, we used a space-for-time substitution approach, in which we assume that MHV activities will generate a transition from fallow to hazelnut orchards. No significant differences in primary productivity were found between fallow and hazelnut orchards for any of the two years analyzed (Figure 7). It is important to notice that the mean age of the orchards at the moment of visit in early 2020 was 7 years (standard deviation = 0.86), meaning that orchards had 4 to 5 years old at the moment the used EO data was collected. Continued monitoring is needed in order to fully assess the impact of these interventions on long term site productivity.

[8] Claverie, M., Ju, J., Masek, J. G., Dungan, J. L., Vermote, E. F., Roger, J.-C., Skakun, S. V., & Justice, C. (2018). The Harmonized Landsat and Sentinel-2 surface reflectance data set. Remote Sensing of Environment, 219, 145-161.

[9] Venables WN, Ripley BD (2002). Modern Applied Statistics with S, Fourth edition. Springer, New York. ISBN 0-387-95457.

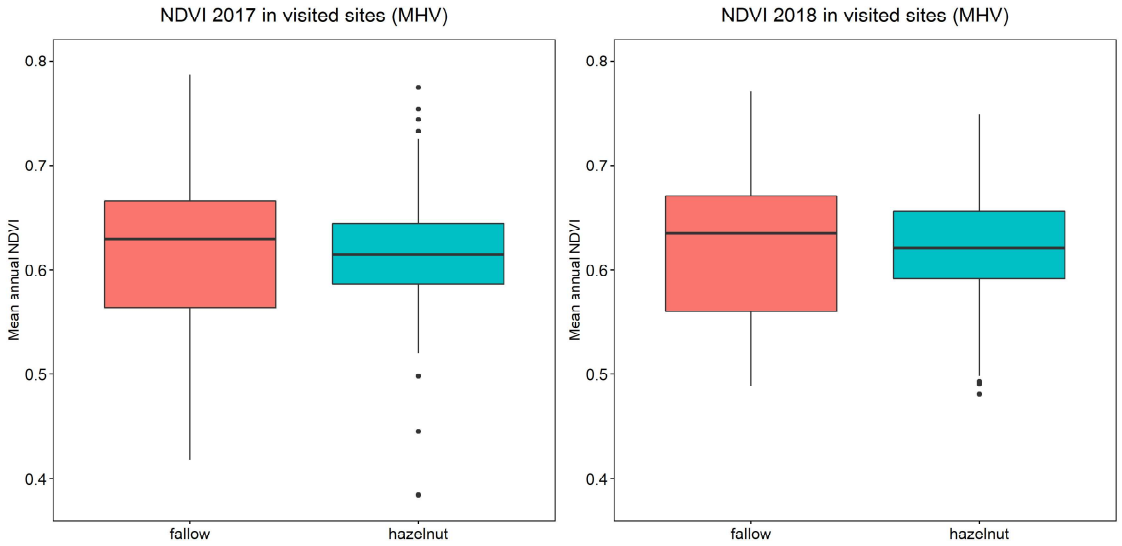

Figure 7. Frequency distribution of annual integrals of NDVI for 2017 and 2018 comparing hazelnut orchards and nearby fallow sites. No significant differences were found between them for any of the years (p-value = 0.30 for 2017 and p-value = 0.42 for 2018)

5.2.Land cover

The Government of Bhutan regularly produces land cover maps at 30 m resolution which can be used for developing the baseline and monitoring progress towards LDN. Using the national land cover map from 2016[10] we developed the land cover baseline assessment for the 10,440 orchards MHV is currently working on (presented in main document) and we evaluated the potential impact of the establishment and management of the orchards using the information collected in the field (Figure 8, right). Almost half of the orchards MHV has established throughout the country of Bhutan were classified as *kamzhing* agriculture (46.1%). This name is used to identify cultivated rain-fed areas in dry lands[5]. Forests represent 25.2 %, shrublands 19.9%, and *chuzhing* agriculture (irrigated and or bench terraced agricultural land for paddy-based cropping systems) 4.4 %.

A space for time substitution approach was used to assess the potential impact of MHV field activities in land cover. Sites identified as fallow for this analysis were selected by MHV personnel and had to be sites which presented similar environmental and management conditions to those in which mountain hazelnut orchards were to be established. By using the national land cover data, we see that most of the fallow sites were classified as agriculture or forest land, while the shrublands represent a significant portion of the sites in which orchards are established.

[10] FRMD, 2017, Land Use and Land Cover of Bhutan 2016, Maps and Statistics. Forest Resources and Management Division, Department of Forests & Park Services, Ministry of Agriculture and Forests, Thimphu, Bhutan. ISBN: 978-99936-743-2-0

Young orchards with not fully developed canopies would explain that difference (note that the national land cover map is from 2016, in which case the mean orchard age would have been of approximately 4 years. Continued monitoring would be required for definitively determining if the incipient increase in woody cover (trees and shrubs combined) identified by this analysis is sustained throughout the lifetime of the project.

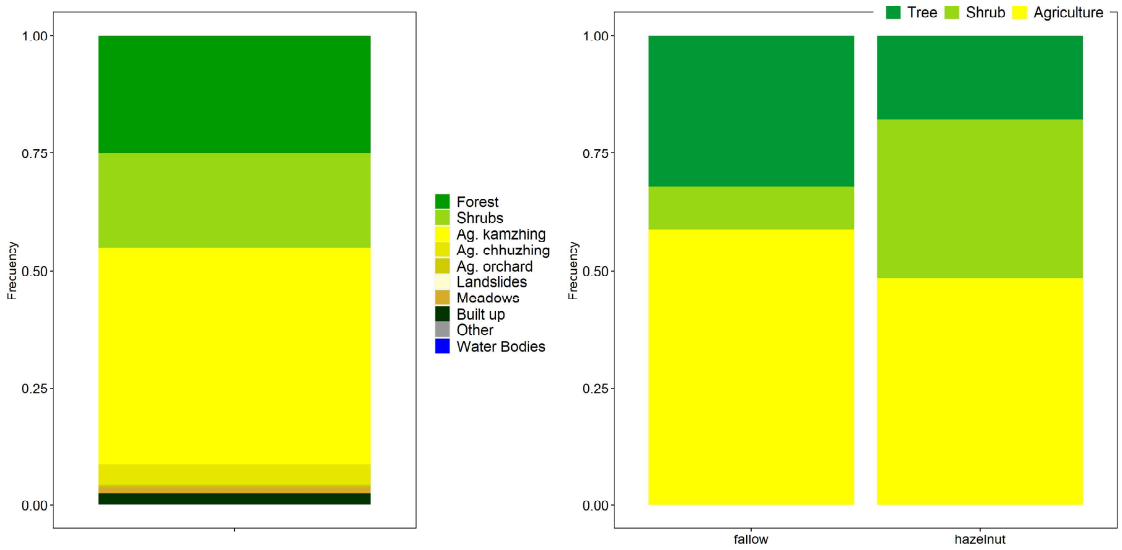

Figure 8. Land cover for MHV orchards in 2016 (left): Almost 50% of the MHV orchards were classified as rainfed agricutlture (Ag. Kamzhing) in 2016, followed by forests (25.2%) and shrubs (19.9%). By comparing land cover between fallow sites and orchards, an initial increase in woody cover is identified in areas managed by MHV.

5.3.Soil organic carbon

The analysis completed for the SOC baseline section, can be interpreted as a reference condition to which to compare progress over time, but they also serve to understand potential changes now of future interventions using a space for time substitution approach. Soil samples were collected using a cluster design to minimize variability in soil conditions among the three type of treatments evaluated within clusters. This design allows us to have an initial understanding on the potential impact of changes in management in SOC as part of the CSN project.
Soils are inherently spatially very variable, and the cluster design tries to minimize that variability in order to detect the effect of the intervention of interest, in this case, the establishment of hazelnut orchards. A two-way analysis of variance was used to assess the significance on the mean differences found between the fallow sites and the orchards, showing a significant increase in SOC stocks after controlling for the cluster effect (p-value < 0.01). Soil in hazelnut orchards had on average 11.9 tons/ha of C more than the fallow sites (Figure 9).

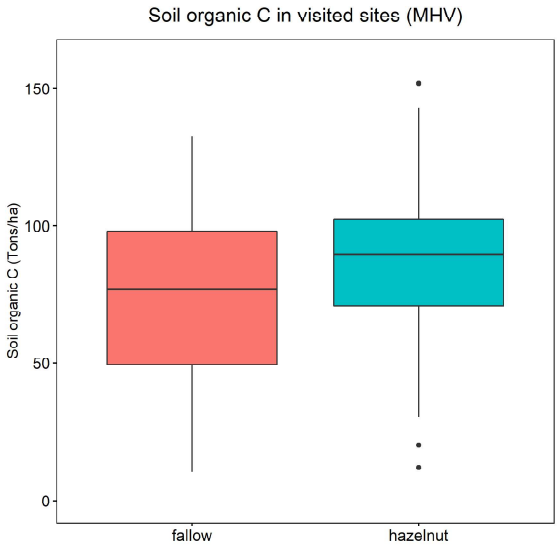

Figure 9. Mean SOC was significantly higher in hazelnut orchards (85.94 tons/ha) than in nearby fallow plots (73.97 tons/ha, p-value < 0.01).