Ecosystem Services Supply, Demand and Values at Chiti, Nepal

Ecosystem-based Adaptation through South-South Cooperation (EbA South)

Final Report

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1 INTRODUCTION

The project “Ecosystem-based Adaptation through South-South Cooperation [1]” is supporting ecosystem-based adaptation (EbA) to climate change risks in several countries. Ecofutures was engaged to support Nepal (one of the pilot countries) to undertake:

- An assessment of ecosystem service changes for a range of ecosystem-based adaptation interventions directed at mitigating climate change risks.
- A cost benefit analysis of the adaptation interventions, using the above ecosystem services analysis, project costs and expert opinion.

The objective of this analysis is to highlight the implications of different climate change adaptation scenarios in Nepal.

The project implemented ecosystem-based adaptation interventions to address climate change risk in number of sites in Nepal. One such site was the Chiti ward, in the Lamjung district (province of Gandaki Pradesh). Chiti is largely a rice farming area immediately west of the town Besisahar and south of the Annapurna Conservation Area. The Chiti ward was selected as a case study for a cost benefit analysis as a wide range of interventions had been undertaken in the area. The interventions were implemented through a collaborative effort by both Government of Nepal and EbA South project team.

2 ECOSYSTEM SERVICES A BASIS FOR EBA IMPACT ANALYSIS

Ecosystem services are the outputs of nature that generate services and benefits for people. Ecosystem services are the service flows generated by the natural capital stocks in a location. It is important to note that ecosystem services are not the same as ecosystem functions. Functions are the biological, chemical, hydrological and geomorphological processes associated with natural ecosystems. Services are the result or outputs of bio-physical processes which people use - directly or indirectly, to generate benefits.

We are familiar with piped water, hydro-electric energy and food security as services, but often neglect to recognise nature’s processes as beneficial services. In the past, Chiti had a comfortable climate with reliable rainfall and river flows, with little or no concern about their future supply reliability. However, with climate change, services such as regular stream flow, consistent seasonal rainfall and food security have become increasingly variable and/or uncertain, with elevated risks to wellbeing. A decline in ecosystem services is a threat to Nepalese society.

[1] The project Ecosystem-based Adaptation through South-South Cooperation (EbA South) is a full-sized GEF project, funded through the Special Climate Change Fund. Officially known under the title "Enhancing Capacity, Knowledge and Technology Support to Build Climate Resilience of Vulnerable Developing Countries", the project is implemented by UN Environment and executed by the National Development and Reform Commission of China, NDRC, through the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, IGSNRR, CAS.

In order to predict the possible changes to ecosystem services, through either current natural resource use trends or ecosystem-based adaptation implemented by the EbA South project, the Ecofutures process was employed. The Ecofutures process[2] combines both available data and local wisdom, in a participatory modelling workshop, to understand system linkages and to predict future changes in the social-ecological system. The process included the development of a systems model (using Excel) to outline and understand the status-quo situation in Chiti in terms of ecosystem services, and then modelled the implications of several plausible future scenarios. The modelling process served to provide indicators of:

- The stock of natural capital (terrestrial and freshwater) within an impact area of Chiti (see Appendix 1) for the location of the area
- The range of ecosystem services supplied and their *relative* supply levels (service supply levels are computed as an index relative to other services, for example, the modelling identifies which services are supplied at high, medium and low levels relative to each other)
- The number of ecosystem service users and the benefits generated through their respective use
- The direction and magnitude of ecosystem services change in different climate adaptation scenarios (including EbA South project interventions)
- The impacts of different intervention scenarios on climate change risk

The process uses ecosystem services as the medium or currency of measuring change, as it is through changes in ecosystem services that humans experience landscape changes. The indicators of change can be used, in conjunction with a cost benefit analysis, to optimise approaches to climate change adaptation.

[2] Ecofutures developed the Ecofutures Process, a participatory ecosystem services supply and demand assessment to share understandings and generate new insights to support decision making in environmental use and management. The process uses ecosystem services as the common currency for communication between ecologists, engineers, planners, residents and government. The Ecofutures process employs social learning, GIS and systems modelling - to combine a range of local experiences, expert knowledge and readily available ecological and social GIS data. The Ecofutures process won two awards in the South African national business innovation programme - **Technology Top 100** – in 2012. It was a winner in the emerging enterprise section, for South African Academy of Engineering Award for 'Excellence in the Management of Research' and Da Vinci Institute Award for 'Excellence in the Management of Systems'. These awards were in recognition of the Ecofutures participatory modelling process of using innovative technology to support environmental management decision making. The awards were made by the Da Vinci Institute, the South African Ministry of Science and Technology, and the Industrial Development Corporation.

3 THE MODELLING PROCESS EMPLOYED FOR CHITI

A participatory modelling workshop or process was held, that involved a wide range of stakeholders in assessing the supply of and demand for ecosystem services in Chiti for a range of future scenarios. The process used is outlined below:

- Collate basic data on land cover in Chiti ward into a Geographic Information System.
- Review published papers and project reports to inform the modelling process.
- Meeting with Ministry of Forestry officials, and other key partners in Kathmandu to discuss and plan the approach.
- Undertake a three-day field assessment of the area to assess the condition of habitats, hydrological linkages and the local demand for ecosystem services.
- Build a social-ecological systems model using Excel for the Chiti ward.
- Map the land cover types to determine the geographic location and size (in hectares).
- Demarcate the boundaries of the impact area. Note that the entire Chiti ward was included as interventions occurred in a dispersed pattern across the landscape.
- Develop a suite of climate change adaptation scenarios based on discussions with stakeholders and project team members.
- Hold a participatory modelling workshop with project team members, Government of Nepal officials and non-governmental organisations. The workshop process reviewed the model inputs, shared understandings of the affected area and interventions, and developed new insights in terms of:
    - The composition, size and condition of the stock of natural capital (the different habitat types).
    - Ecosystem services supply potentials for the different categories of natural capital and settlements.
    - Ecosystem services' supply levels per land cover type.
    - The demand for ecosystem services, including:
        - The numbers of service users.
        - The relative dependence of users on specific services.
- A baseline model was established representing the pre-intervention scenario (or essentially the status quo). Thereafter the workshop evaluated the changes to service supply levels in future scenarios for 2048. A thirty-year time horizon was employed to encourage the participants to imagine the most realistic scenarios. The following scenarios were developed:
    - A no-intervention scenario – what could the Chiti ward be like in 2048 without any interventions and with climate change impacts.
    - An expanded EbA project intervention scenario – what could the Chiti ward be like in 2048 if the current suite of interventions were upscaled to a realistic level for the Chiti ward. Note that the current EbA South project interventions are relatively small in area and widely dispersed across the Chiti landscape. The current pilot interventions have directly changed some 30 discrete hectares within a 1767 hectare impact area, and consequently the resulting change on the entire area is limited and difficult to measure. The workshop team therefore agreed that the best way to show the benefits of the intervention, was to develop a scenario which upscaled the project interventions to a level that was appropriate and plausible for the entire Chiti ward. In this way, the social and ecological gains could be modelled and the resulting benefits from the project could then be discerned and communicated.

- An expanded agroforestry scenario – switching conventional rice farming to intensive agroforestry.

The discussion on future scenarios included:

- Switching the allocation of areas between different land cover types, such as reducing croplands and fallow lands and increasing settlement and agroforestry areas.
- Changing the condition or state of freshwater and terrestrial habitat types, in response to interventions, climate change, human population pressures and changes in other habitat conditions.
- Systematically reflecting on the consequences of changes in the ecosystems, in relation to hydrological fluctuations, such as when the forests decline in condition and result in reduced infiltration and elevated runoff.
- All the changes were reflected as area changes (in hectares) or as condition changes (as scores) or both.

- The outcomes, in terms of services supply and demand, were then modelled and reviewed. Any anomalies were discussed and either accepted, or if required, changes were made to the criteria scores to address anomalies.
  - The process generated a common mental model of the Chiti ward social-ecological system for the status quo, and then for several plausible future management scenarios.
  - The process facilitated a lively discussion on land cover conditions, land cover areas and numbers of service users, and the likely changes in future land uses/cover.
- The stakeholder workshop was undertaken on the 19th and 20th November 2018 in Kathmandu and included the following participants.

Name	Organization
Bishnu Adhikari	Central Department of Geography, Tribhuwan University
Sher Bahadur Gurung	Central Department of Geography, Tribhuwan University
Jyoti Karki	Central Department of Geography, Tribhuwan University
Bhumi Raj Budhathoki	Tri-Chandra Multiple College
Bhoj Bahadur Ayer	Green Globe
Ram P. Awasthi	Ministry of Forests and Environment
Sanjay Tiwari	Ministry of Forests and Environment
Bishnu Maharjan	Resources Himalaya Foundation
Bimal Kumar Acharya	Ministry of Forests and Environment

Ramji Bogati	Resources Himalaya Foundation
Basanta Babu Shrestha	Ministry of Forests and Environment
Anup Ghimire	Ministry of Forests and Environment
Surendra Raj Pant	Ministry of Forests and Environment
Tej Kumar Shrestha	Ecosystem-based Adaptation through South-South Cooperation
Nirajan Khadka	Nepal Foresters' Associations
Dipak Khadka	Golden Gate International college
Som Nath Gautam	Ministry of Forests and Environment
Srijana Shreshta	REDD Implementation Centre
Arun P. Bhatta	Ministry of Forests and Environment
Sabina M. Prajapati	Forest Research and Training Centre
Shanta Ram Baral	Department of Forests and Soil Conservation
Rojina Shrestha	Department of Forests and Soil Conservation
Anil Kumar Shrestha	Department of Forests and Soil Conservation
Diwen Tan	UNEP-IEMP
Tatirose Vijitpan	UNEP-IEMP
Anish Parajuli	Ecosystem-based Adaptation through South-South Cooperation
Pawan Paudyal	Centre for Green Economy Development, Nepal
Akhanda Sharma	Ministry of Forests and Environment
Myles Mander	Futureworks
Bijaya Mishra	Upper Trisuli '3A' Environmental Expert, Nepal Electricity Authority

Ram Hari Pantha	Ministry of Forests and Environment

- The modelling outcomes are a product of the discussions of the above group, published papers, GIS analysis and field observations, with the report reflecting the opinions and perspectives of the information sources.

4 CHITI WARD NATURAL CAPITAL AND THE ECOSYSTEM SERVICES ANALYSED

For modelling purposes, a locality map was developed with key land cover or habitat types and illustrated Appendix 1. The impact area was the entire Chiti ward as interventions were distributed across the landscape. The land cover types found within the area were as follows:

- Forest - closed canopy deciduous forest with both native and alien plant species
- Wetlands – low-lying areas permanently or temporarily inundated by water
- Settlement – buildings, roads and industry
- Major rivers – large rivers such as the Marshyangdi river
- Minor Rivers - a 10 meter-wide zone that includes the perennial streams and their associated terrestrial river banks
- Grasslands – open areas dominated by grasslands
- Shrublands – areas dominated by low growing plant species which often occupy drainage lines, and may also constitute degraded forests
- Orchards – areas dominated by fruit tree species adjacent to buildings, and may contain croplands
- Terraced croplands – areas dominated by terraced croplands
- Waterbodies – water impoundments, dams or lakes
- Agroforestry – areas dominated agroforestry, which is a combination of high value tree species and crops
- Fallows – areas of terraces which are no longer cropped and largely grass dominated
- Plantations - planted areas of alien tree species

The percentage contribution of the discrete landcovers to the stock of natural capital is illustrated in Figure 1. The landcover categories include both natural assets and built assets. In terms of natural assets, the focus was on renewable natural assets which, if managed and used sustainably, have the capacity to regenerate themselves, providing benefits and reducing climate change risks to people in perpetuity. Note that settlements and terraced croplands also contain ecological and hydrological processes which benefit society, such as food and water quality maintenance. This analysis did not consider non-renewable natural assets (e.g. subsurface oil, gas, minerals and aggregates).

The condition or state of the stock of natural assets[3], was assessed by a field assessment with the government and project team, and then reviewed by the workshop. These are illustrated in Figure 2.

[3] The condition scores are an average condition based on the observers' perceptions of functionality enhancing factors such as: limited edge to area ratio, natural fire regime, good ground cover, limited erosion, limited alien invasive plants, presence / habitat for rare species, sustainable resource harvesting, adequate ecotone, sustainable clearing, natural water flows, limited sedimentation, adequate fallow periods, restorative crop mixes, presence of forest animals, limited pollution, high productivity, contiguous or unfragmented habitats, similar habitats close by and key ecological inputs available. The scores are generated through sharing of perceptions by the workshop participants (based on observations or research), and then agreeing on an average state or condition.

The natural capital discussed above, generates a suite of ecosystem services which are used directly or indirectly by humans. Note that the size and the condition of the assets determine the functionality of the assets and consequently the level of services it can supply. For example, a largely intact and highly functional forest is capable of supplying high levels of water supply regulation, wood fuel energy and timber services. However, if the forest is fragmented, degraded, reduced in size and invaded by alien tree species, its functionality will be reduced, and the associated services levels will decline.

The following ecosystem services were identified as being important (by the author) and were adapted and analysed by the modelling workshop:

- Wild animals for consumption – such as fish and mammals by small scale fishermen
- National Biodiversity Conservation Objectives - a space to meet national objectives for the conservation of landscapes, or percentages of habitat types conserved
- Carbon storage - carbon capture and storage by terrestrial habitats
- Cultural heritage - provision of special spaces (such as river confluences) or species for the maintenance of cultural practices
- Disease control - the reduction of disease pathogens in water and terrestrial habitats
- Flood reduction - the reduction of flood risk through the reduction of run-off and slowing of surface water flows due to dense ground cover
- Fodder / grazing - access to natural pastures for cattle, goats and water buffalo
- Fuel (wood & charcoal) – a source of energy for domestic energy demand
- Medicinals - a source of plant-based medicines
- Pollination - the pollination of fruiting trees and legume crops by bees and other pollinating insects
- Plants for food (wild & cultivated) - food plants such as grain crops (rice and maize) and fruit
- Plants for construction - poles and other timber and non-timber products for homestead construction
- Recreation - places for recreation such as swimming, trekking, bird watching, white-water rafting, etc
- Soil formation and fertility - the maintenance of cropland soils fertility by ecological processes
- Soil stability (erosion control) - slope and cropland stabilisation due to dense plant cover and binding roots
- Water supply - abstraction of adequate water quantities for consumption and production
- Water quality - the dilution and assimilation of organic and in-organic pollutants by ecosystems
- Water supply regulation - the regulation of water supply through elevated infiltration and slow release back into rivers, providing access to water during the dry season
- Green energy (biogas, hydro or solar) - access to green energy options due to crop plants, animal waste or river flows

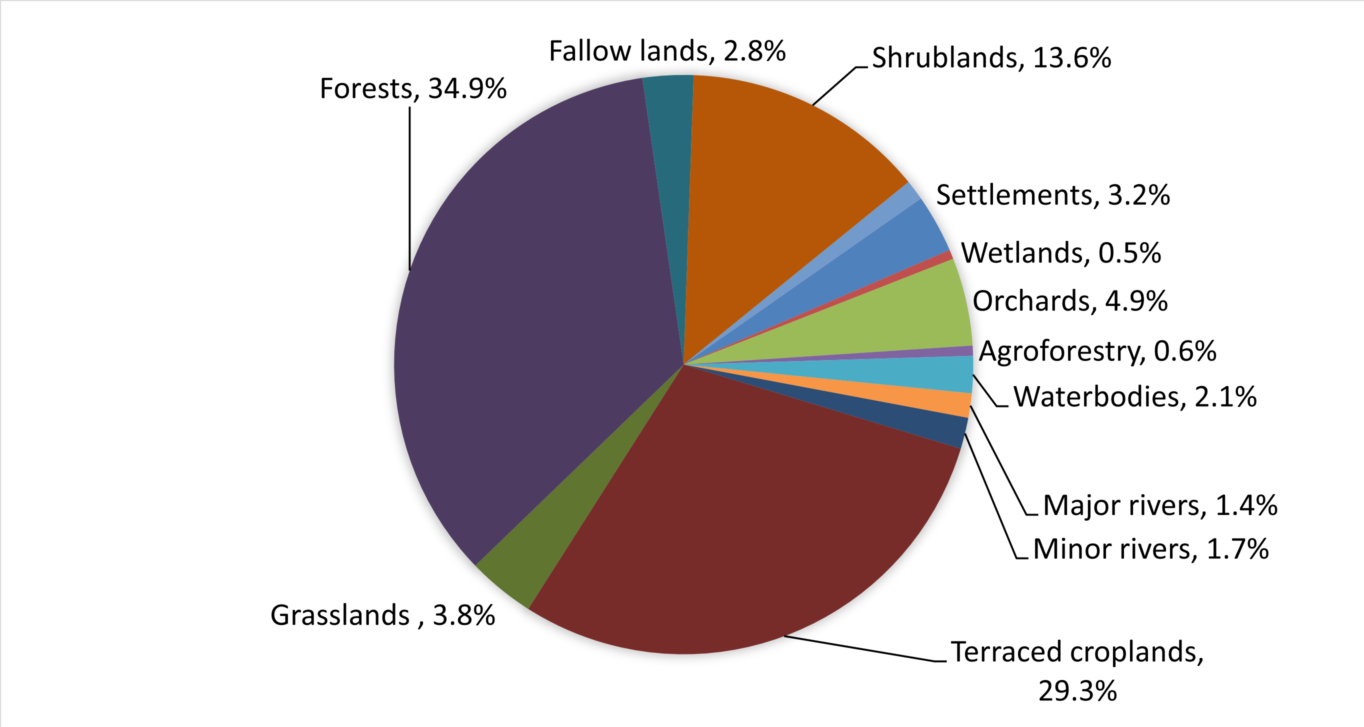

Figure 1: The relative contribution of the landscape assets to total area of Chiti ward (1 767 ha)

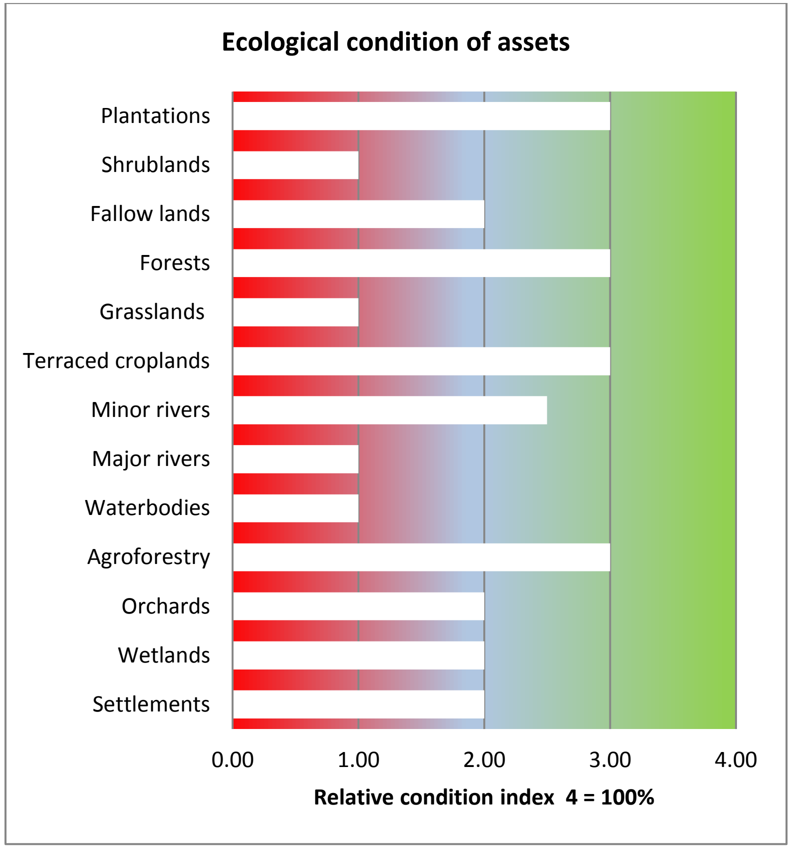

Figure 2: Condition of natural and built assets in Chiti ward in 2018 (at the time of the intervention)

Implications for climate change adaptation:

- There are a wide range of land cover types or habitats present in the impact area. This implies that interventions in the social-ecological system need to consider impacts on a wide range of ecological processes.
- There are strong hydrological linkages between the different habitat types. For example, in terms of downstream flows, the forests are linked to stream flows and hydro-electric generation potential. The degradation of forests will result in accelerated run-off and erosion, sediment mobilisation and will accumulate in water bodies, where it may lead to reduced water storage capacity and elevated levels of turbine erosion – both which generate high maintenance costs.

Furthermore, the elevated run-off will result in less infiltration, less ground water storage and less dry season water. The elevated run-off also contributes to greater flooding and infrastructure damage.

- The habitats were generally in poor and moderate condition. This implies that the social-ecological system is vulnerable to climate change perturbations, such as high rainfall events, flooding and droughts. The degraded condition of the habitats implies that much can be done to promote resilience and welfare by improving the condition of the natural capital stock, thereby increasing functionality and elevated services supply.
- There are a wide range of services associated with or produced by the Chiti natural capital. This implies that intervening in the system impacts on numerous services and therefore the numerous service users.

5 THE SUPPLY OF ECOSYSTEM SERVICES IN CHITI WARD

Each of the natural assets or built assets have a unique capacity to supply different ecosystem services. For example, hardened surfaces such as roads have no ability to promote water infiltration and consequently cannot reduce floods or promote ground water recharge. On the other hand, paddy fields have a high capacity to promote infiltration and reduce flooding with the numerous terraces and bunds (little dam walls). Furthermore, the vertical terrace walls in paddy fields are usually vegetated with native species, contributing to biodiversity conservation. In the modelling process, each habitat may have a zero, low (1 score), low medium (2 score), medium high (3 score) or high capability (4 score) to supply different ecosystem services (see

ECOSYSTEM SERVICES	Settlements	Wetlands	Orchards	Agroforestry	Waterbodies	Major rivers	Minor rivers	Terraced croplands	Grasslands	Forests	Fallow lands	Shrublands	Plantations
Wild animals for consumption	0	1	0	1	3	2	1	1	0	2	0	0	0
Biodiversity Conservation	0	4	0	0	0	4	2	1	1	3	1	1	0
Carbon storage	0	2	2	2	0	0	1	1	3	4	2	2	3
Cultural heritage	4	0	1	0	0	1	2	1	0	2	0	0	0
Disease control	0	3	1	1	0	2	1	1	1	4	1	2	2
Flood reduction	0	3	2	3	2	0	0	3	2	4	1	2	3
Fodder / grazing	0	4	2	3	0	0	1	1	4	2	3	2	0
Fuel (wood & charcoal)	0	0	1	2	0	0	1	0	0	4	1	2	3
Medicinals	0	0	0	2	0	0	0	1	1	3	0	1	1
Pollination	0	1	2	4	0	0	0	1	2	4	2	2	3
Plants for food (wild & cultivated)	0	1	2	3	0	0	0	4	0	1	0	0	0
Plants for construction	0	1	0	2	0	0	0	0	0	3	0	2	4
Recreation	2	0	0	0	3	1	2	0	0	1	0	0	0
Soil formation and fertility	0	4	0	2	0	0	0	0	1	4	1	1	0
Soil stability (erosion control)	0	4	2	3	0	0	1	3	1	4	2	2	2
Water supply	0	0	0	0	4	4	3	0	0	0	0	0	0
Water quality	0	3	1	1	2	4	2	1	1	3	1	1	1
Water supply regulation	0	3	1	2	4	0	0	3	1	3	1	1	0
Green energy	2	0	0	0	4	2	0	0	0	0	0	0	0

Table 1). These service supply capabilities can be considered inherent (and are therefore kept constant in the model) and used together with habitat functionality (which changes), to compute the relative services supply levels or changes in supply levels. Importantly, as each future scenario alters the functionality of the habitat type, the service levels change in response.

ECOSYSTEM SERVICES	Settlements	Wetlands	Orchards	Agroforestry	Waterbodies	Major rivers	Minor rivers	Terraced croplands	Grasslands	Forests	Fallow lands	Shrublands	Plantations
Wild animals for consumption	0	1	0	1	3	2	1	1	0	2	0	0	0
Biodiversity Conservation	0	4	0	0	0	4	2	1	1	3	1	1	0
Carbon storage	0	2	2	2	0	0	1	1	3	4	2	2	3
Cultural heritage	4	0	1	0	0	1	2	1	0	2	0	0	0
Disease control	0	3	1	1	0	2	1	1	1	4	1	2	2
Flood reduction	0	3	2	3	2	0	0	3	2	4	1	2	3
Fodder / grazing	0	4	2	3	0	0	1	1	4	2	3	2	0
Fuel (wood & charcoal)	0	0	1	2	0	0	1	0	0	4	1	2	3
Medicinals	0	0	0	2	0	0	0	1	1	3	0	1	1
Pollination	0	1	2	4	0	0	0	1	2	4	2	2	3
Plants for food (wild & cultivated)	0	1	2	3	0	0	0	4	0	1	0	0	0
Plants for construction	0	1	0	2	0	0	0	0	0	3	0	2	4
Recreation	2	0	0	0	3	1	2	0	0	1	0	0	0
Soil formation and fertility	0	4	0	2	0	0	0	0	1	4	1	1	0
Soil stability (erosion control)	0	4	2	3	0	0	1	3	1	4	2	2	2
Water supply	0	0	0	0	4	4	3	0	0	0	0	0	0
Water quality	0	3	1	1	2	4	2	1	1	3	1	1	1
Water supply regulation	0	3	1	2	4	0	0	3	1	3	1	1	0
Green energy	2	0	0	0	4	2	0	0	0	0	0	0	0

Table 1: Ecosystem service supply capability by habitats in pristine condition (scores range from 0 (zero - red) to 4 (very high - dark green)

By combining the capability scores with ecosystem functionality (that is, the product of the scores), it is possible to indicate the relative contribution of each habitat type to the supply of discrete services. Figure 3 illustrates the relative contribution of each habitat type to the supply of a particular service (see Appendix 2 for the spatial distribution of services). For example, in terms of water supply regulation services, forests and terraced croplands are the two dominant suppliers, with forests contributing some 50% and terraced croplands contributing some 40% of the water supply regulation service. Consequently, any changes to the condition and/or size of forests and terraced croplands will have large-scale impacts on water supply regulation services. On the other hand, if the desire is to enhance water supply, then the minor rivers' ecological condition is going to play a critical role, as they contribute some 42% of supply (note that one cannot increase the size of rivers). Note that the Chiti forests dominate service supply and consequently any improvement in the size and condition of forests are likely to promote resilience to climate change. Conversely, any decrease in forest condition or size, will generate greater risks to key services, and less resilience to climate change. See Appendix 3 for the spatial location of areas with high to low levels of service supply.

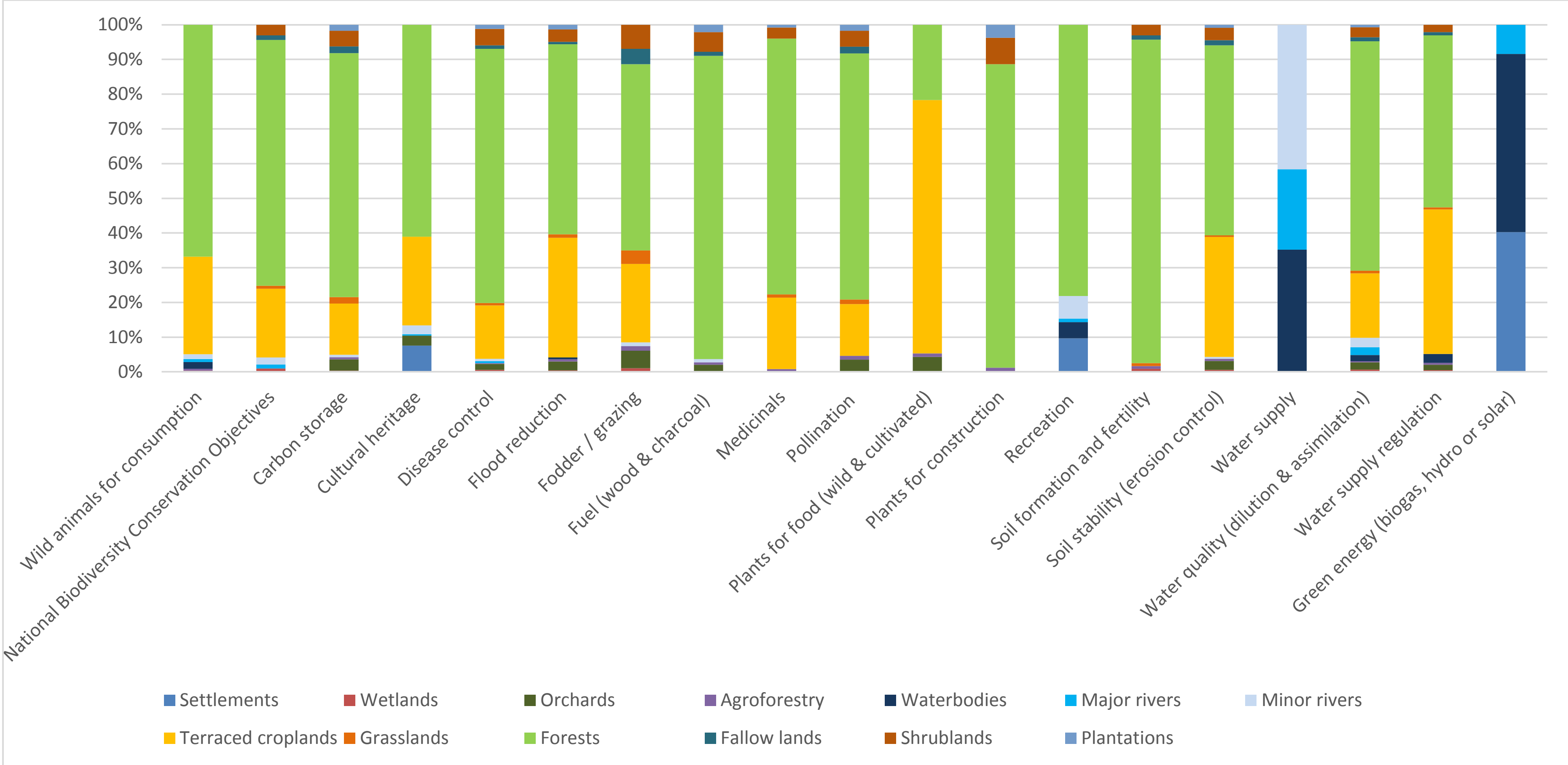

Figure 3: The relative contribution of discrete ecosystem services per land cover type

Figure 4 shows the range and relative levels[4] of services supplied by each of the land cover types in 2018, at the time of the EbA interventions, and constitutes the baseline situation which is used to generate and analyse future scenarios. Importantly, the service levels shown are an index relative to each other, showing relative abundance and

[4] The relative levels are a product of functionality (a weighted score of area and condition) and service supply capabilities (an inherent capability in pristine conditions).

scarcity. Services clustered on the left are relatively abundant (such as flood reduction and soil stability (or erosion control), while services on the right are relatively scarce (such as water supply and green energy).

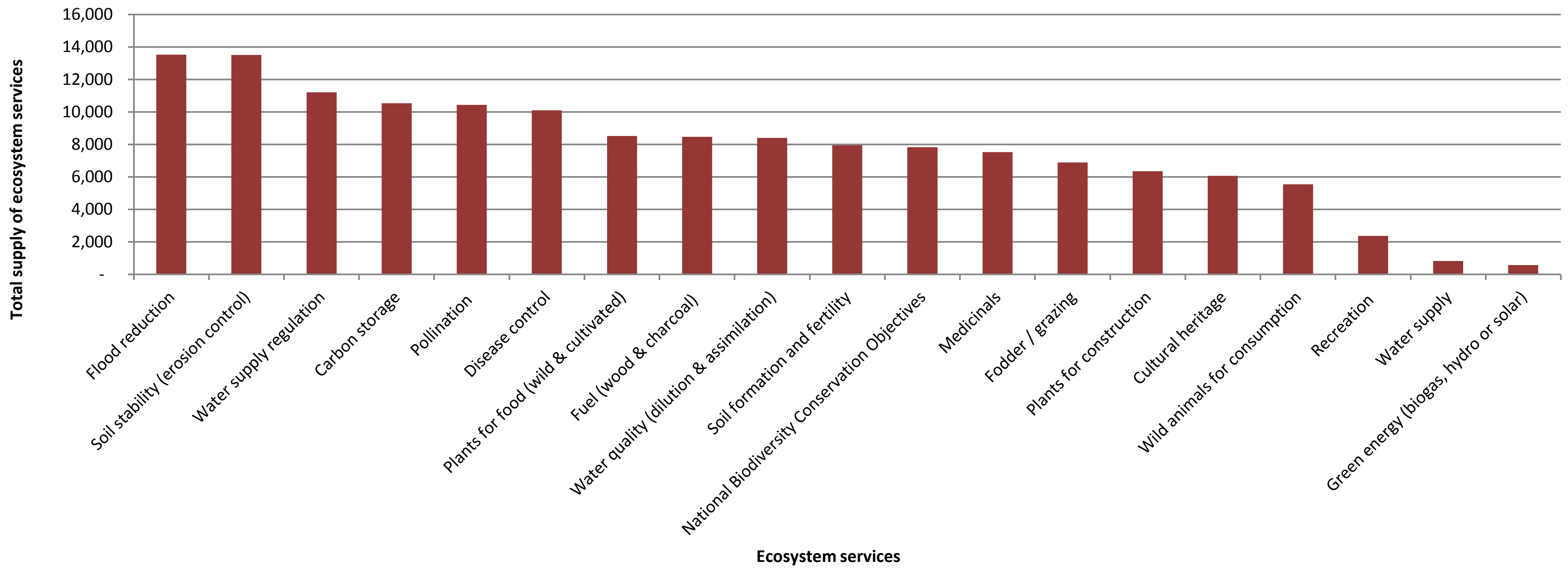

Figure 4: Graph showing the 2018 relative levels of ecosystem services supplied (as an index) by ecosystems

The implications for climate change adaptation are that:

- The natural capital in Chiti can play an important role in mitigating the impacts of climate change in society, and include:
  - Protecting energy security, in terms of hydro power by promoting soil stability, erosion control and water supply regulation, thereby preventing flooding, sedimentation of waterbodies and turbine erosion, and in promoting a regulated water supply. Climate change is likely to elevate rainfall intensity which may contribute to greater run-off and greater sediment loads. In terms of wood fuel energy, forests provide energy and agriculture by-products offer biogas.

- Protecting food security, by promoting food supply, and supported by soil stability, pollination, disease control, soil fertility and dry season water (water supply regulation). Climate change may alter the seasonality and intensity of rainfall, and ecosystem services can make the production more resilient to these changes by providing a buffer to variability and extreme events.
- Promoting water security, by elevating water supply regulation or providing elevated assurance of supply in drought periods which may be exacerbated by climate change.
- Promoting income generation security. As described above, greater resilience in food production will offer local households greater security in earning incomes from food produced or traded.
- Promoting health security. Note that water supply is critical for health security and is currently the relatively scarcest service (as it is only supplied by a small network of streams). This situation is likely to be aggravated by climate change in dry seasons by reducing water availability and a greater population increasing human waste production containing pathogens. This implies there will be greater pollution loads and less dilution and assimilation capabilities, probably contributing to significantly higher risks to human health. Promoting greater dry season flows in droughts will be critical to maintain human health.

- While climate change has the potential to degrade ecosystems and reduce service levels, the problem is exacerbated by the ongoing erosion of natural capital, over-use (harvesting) of ecosystems, increase in pollution discharge, infestation by alien species and water flow disruptions (alien plant evapotranspiration, accelerated runoff, abstraction and diversion). The current trends imply that climate change impacts may be compounded by currently inadequate environment management. Without ecosystem-based adaptation measures, natural capital services will need to be replaced by built capital services, using scarce financial capital. It is unlikely that this will be affordable in Chiti and maintenance of existing natural capital or ecological infrastructure will by far be the cheapest option facing Nepalese society.

6 THE DEMAND FOR AND BENEFITS OF CHITI WARD ECOSYSTEM SERVICES

The above discussion on ecosystem services supplied and their relative levels, needs to be seen in the context of the demand for ecosystem services. For example, if a service is relatively abundant and declines due to functionality changes, but there is little demand for the service, then there are minor implications for Nepalese society. On the other hand, if a service is relatively scarce and demand levels are high, then any service levels declines are likely to result in serious welfare losses for the users. An analysis of ecosystem services' demand helps to identify risks and prioritize interventions.

Table 2 outlines the demand and benefits generated for each of the ecosystem services. The total number of beneficiaries were estimated by the workshop, based on census data, local observations and available estimates. Note that the beneficiaries may be comprised of different levels of vulnerability or dependence, with some users having a: i) critical dependence (or lifesaving /life changing impact), ii) high dependence (key service for livelihoods used regularly), iii) moderate dependence (a service playing a moderately important role in livelihoods), and iv) a low dependence (a service used a few days a year and not important for livelihoods). Note that the numbers below the dependence headings, indicate the weighting used. The Human Benefit Index[5] combines different users of different intensity and frequency of use, to create a single weighted benefit score, that permits comparisons between services (Figure 5) or between different scenarios. Simply put, one could conceptualise the Human Benefit Index as the number of full-time users, highly dependent on the service which is made up of 'full-time' and 'part-time' users of variable dependence.

The Human Benefit Index shows the benefits generated by the different ecosystem services. Table 2 and Figure 5 shows which services have the greatest benefit to society compared to the lowest benefit levels. It also shows which services have critical (red), high (orange), medium (yellow) and low (blue) dependence scores. Note the following:

- The national biodiversity conservation objectives have the greatest human benefit index, as this is driven by the large national population. However, note that dependence is low (see the blue column in Figure 5) as other areas can also supply this conservation service.
- Second highest services are green energy and soil stability, as these services serve not only the Chiti population but over 100 000 district electricity users. Note that these users are critically dependent on the Chiti services. The soil stability service promotes the sustainability of the green energy service.
- At the local Chiti level, and some additional adjacent users, most households (there are some 1299 households in Chiti with a population of 5166 people[6]) have critical dependence of ecosystem services that support food security, water security, homestead construction, health security, energy security and income generation. Note that in many cases, the number of service users exceed the Chiti population, as some services are exported to other users, usually downstream (natural flows) or in adjacent Besisahar (products traded).

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[5] Cartwright, A., Blignaut, J., De Wit, M., Goldberg, K., Mander, M., O'Donoghue, S. and Roberts, D. 2013. Economics of climate change adaptation at the local scale under conditions of uncertainty and resource constraints: the case of Durban, South Africa. Environment and Urbanization. https://doi.org/10.1177%2F0956247813477814

[6] National Population Report 2017. Ministry of Population and Environment (MoPE), Singha Durbar, Kathmandu

The different human benefit indices highlight the need to consider the full range of services when selecting climate change responses. Note that the Chiti natural assets play a national conservation role, a critical district energy security role and a critical role local households' livelihoods and wellbeing. To optimise a net social gain, it is critical to consider all the key service changes and especially their impact on vulnerable users.

ECOSYSTEM SERVICES	Total number of beneficiaries	% Critical dependence	% High dependence	% Moderate dependence	% Low dependence	Human Benefit Index
		Weight 1	Weight 0.5	Weight 0.25	Weight 0.01	Weighted benefit score
Wild animals for consumption	258		50%	50%		97
National Biodiversity Conservation Objectives	27 000 000				100%	270 270
Carbon storage	517		10.00%	90.00%		142
Cultural heritage	517		10%	90%		142
Disease control	4 649	90%	10%			4 417
Flood reduction	10 000	10%	30%	50%	10%	3 760
Fodder / grazing	4 649	30.0%	60.00%	10.00%	0%	2 906
Fuel (wood & charcoal)	5 063	30.0%	60.00%	10.00%		3 164
Medicinals	3 616	10%	40%	40%	10%	1 450
Pollination	5 166	90%	10%			4 908
Plants for food (wild & cultivated)	9 000	90%	10%			8 550
Plants for construction	6 000	90%	10%			5 700
Recreation	1 550		20%	80%		465
Soil formation and fertility	4 649	90%	10%			4 417
Soil stability (erosion control)	117 407	70%	30%			99 796
Water supply	7 000	100%				7 000
Water quality (dilution & assimilation)	7 000	100%				7 000
Water supply regulation	7 000	100%				7 000
Green energy (biogas, hydro or solar)	117 407	70%	30%			99 796

Table 2: The demand for ecosystem services and their associated Human Benefit Index (red shading denotes highest human benefit while the green denotes the lowest benefit levels)

Implications for climate change adaptation:

- The Nepalese Government should identify which climate change responses will offer the greatest net benefit to society. In other words, which action will offer the greatest level of benefits per Rupee spent. For example, forests in Chiti are major generators of; i) conservation services (which benefit the nation), ii) erosion control (which benefit the district population in terms of energy security) and iii) water supply regulation, water quality, energy, construction materials, pollination and flood reduction (all of which are critical for local households). An intervention which promotes forest functionality is likely to offer Nepalese society the greatest package of services and benefits. Investing in functional forests could be considered a buffer or an insurance against climate change perturbations or impacts, and they also offer other valuable services, irrespective of climate change. Consequently, forest restoration and conservation can be considered a No Regret Approach which generates benefits with or without climate change.
- The second most useful intervention is likely to be management of paddy fields which offer district and local benefits (and may be politically more attractive).
- Focussing interventions on single user groups, such as food producers, is likely to produce suboptimal outcomes in terms of human wellbeing and economic benefits.

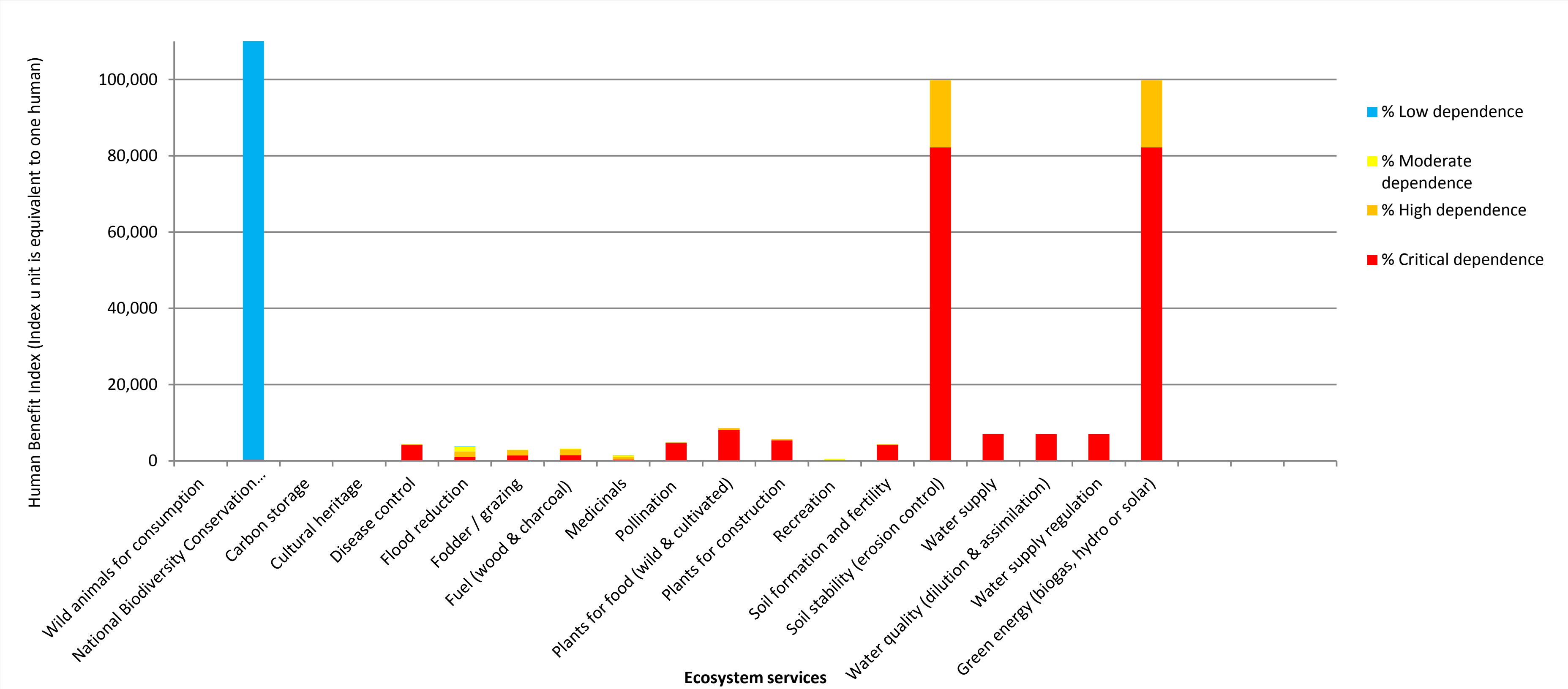


Figure 5: The relative human benefits of the Chiti ecosystem services supplied (note the vertical axis is limited to 110 000 to allow local level comparisons)

7 THE ECOSYSTEM-BASED ADAPTATION SCENARIOS FOR CHITI WARD

To better understand the benefits of the EbA South project interventions in Nepal it was necessary to develop a range of scenarios. The scenarios used are outlined below. Table 3 shows the changes in the composition (which habitat type), changes in size (estimated in hectares) and changes in condition (in terms of a four-point score, with score 1 = 25% of pristine condition, score 2 = 50% of pristine condition, score 3 = 75% of pristine condition and score 4 = 100% of pristine condition) of natural and built capital associated with each scenario. These changes were discussed extensively and agreed on in the Kathmandu workshop and the reasoning is not documented in this report. Changing the composition, size and condition of natural and built capital results in changes to ecosystem services' supply levels. These changing levels were computed by the Ecofutures model and illustrated in Figure 6.

The climate change scenarios modelled were as follows:

- **2017 Pre-intervention scenario** – this is the baseline scenario or yardstick to build the future scenarios. This scenario reflects the situation prior to the project interventions (such as planting high value tree species in fallow lands, converting marginal rice croplands to agroforestry, enrichment planting in degraded shrublands, and enrichment planting in forests). In the radar graph below, the red line denotes the status quo in terms of the service supply levels when all services are normalised to 100%. Any changes in service levels in other scenarios are then reflected as either a shift above or below 100% supply level (red line).
- **2048 Without the Intervention Scenario** – to understand the magnitude of benefits which EbA may generate, it is necessary to determine the difference between a future 'with' and 'without' an intervention environment. Consequently, the impacts of climate change (such a greater seasonal variability, greater rainfall variability and more prolonged droughts) in the Lumjung district need to be built into all the future scenarios. In this scenario, it assumes climate change occurs, no remedial intervention takes place, natural resources continue to be highly utilised, population doubles due to migration out of remote mountain villages (due to climate change and modernisation despite Lumjung district's average of zero growth) into areas close to Besisahar and pollution discharge doubles. Settlements grow at the expense of croplands, fallow lands, shrublands and forests. Furthermore, growing demand for food results in further conversion of shrublands, grasslands and forests. A large resident population degrades forests' and minor rivers' conditions. Elevated run-off associated with a highly energised atmosphere and elevated grazing and agriculture intensity, results in greater sedimentation of the Marshyangdi river impoundment, reducing the volume of the dam and producing an upstream wetland. In this scenario water quality declines as a result of increased settlement and a reduction of the forest's buffer effect. This leads to impacts, such as sedimentation, high nutrient loads and high bacterial loads being transferred to downstream communities along Chiti streams and ultimately the Marshyangdi river and associated impoundment. The consequences of these changes are a reduction in most of the ecosystem service levels. Figure 6 shows that there could be contraction in services of between 20% to 60% (with the greatest reduction being water supply). This implies that there will be double the people and far fewer services, with a consequent decline in services per capita. Much of the decline is due to a combination of both increased human pressure, land transformation and climate change. The one exception is green energy which grows as bioenergy, solar energy and other energy innovations are adopted due to ongoing technology innovation and market prices.
- **2048 With Expanded EbA South Scenario** – in this scenario, the EbA South project intervenes with:
    - planting high value tree species in fallow lands,
    - converting marginal croplands to agroforestry,

- enrichment planting in degraded shrublands,
- enrichment planting in forests,
- promotion of energy efficient stoves and lights and
- diversifying income earning potential by making high value fruit and bee products accessible.

The 2048 With Expanded EbA South scenario builds on the no intervention scenario by accounting for climate change, population growth, settlement growth but includes an expanded EbA interventions programme. Note that in this scenario, the current suite of EbA South project interventions are upscaled significantly to evaluate its impacts at a landscape level[7]. In this scenario fallow lands, shrublands and grasslands decline in response to settlement growth and agriculture expansion. A large proportion of the croplands are replaced with well managed high value crops such as fruit orchards and agroforestry. The remaining terraced croplands improve in condition. Forest area is retained through good management, but with a slight decline in condition. Water impoundments and major rivers decline in condition, and the impoundment also declines in area due to upstream sediments. In summary, there is a contraction in natural ecosystems as settlement and agriculture grows, but the key asset, forest, is largely retained. The implications for ecosystem services is a modest expansion in most services, with biomass energy, food crops, fodder and pollination growing the most. On the other hand, water supply and national biodiversity conservation services contract. Importantly, despite double the population, water supply regulation and water quality are held constant.

- **2048 Expanded Agroforestry Scenario** – this scenario is similar to the 2048 With Expanded EbA South scenario, except that most of the terraced croplands are converted to agroforestry. In this scenario the relatively low value rice production is replaced by higher value agroforestry fruit, fodder, fuel and legume food crops. The greatest benefit of this scenario is elevated ground cover and greater biomass, resulting in stable and more fertile soils, greater fuel, fodder, medicinals, construction materials and pollination, but with slightly less food. Importantly, the elevated ground cover reduces run-off, erosion and sedimentation, resulting in improved water quality services and improved conditions in the minor rivers and streams.

[7] As the project interventions occurred at a small scale and were widely spaced within the Chiti ward (pilot approach), it was necessary to expand the interventions in order to discern a measurable change at the ward level on the environment.

2017 Pre-intervention													
ECOLOGICAL ASSETS	Settlements	Wetlands	Orchards	Agroforestry	Waterbodies	Major rivers	Minor rivers	Terraced croplands	Grasslands	Forests	Fallow lands	Shrublands	Plantations
CONDITION - score relative to its potential - 4 to 0	2.0	2.0	2.0	3.0	1.0	1.0	2.5	3.0	1.0	3.0	2.0	1.0	3.0
SIZE - area in ha	57	9	87	10	37	24	31	518	67	617	50	240	20
Percentage of total	3.2%	0.5%	4.9%	0.6%	2.1%	1.4%	1.7%	29.3%	3.8%	34.9%	2.8%	13.6%	1.1%

2048 Without intervention													
ECOLOGICAL ASSETS	Settlements	Wetlands	Orchards	Agroforestry	Waterbodies	Major rivers	Minor rivers	Terraced croplands	Grasslands	Forests	Fallow lands	Shrublands	Plantations
CONDITION - score relative to its potential	2.5	1.0	2.0	2.5	0.5	0.5	0.5	2.0	0.5	2.5	0.0	0.5	1.0
SIZE - area in ha	157	24	87	100	22	24	31	718	17	427	0	140	20
Percentage of total	8.9%	1.4%	4.9%	5.7%	1.2%	1.4%	1.7%	40.6%	0.9%	24.2%	0.0%	7.9%	1.1%

2048 With expanded EbA South													
ECOLOGICAL ASSETS	Settlements	Wetlands	Orchards	Agroforestry	Waterbodies	Major rivers	Minor rivers	Terraced croplands	Grasslands	Forests	Fallow lands	Shrublands	Plantations
CONDITION - score relative to its potential	3.0	2.0	3.5	3.5	1.0	1.0	2.0	3.5	0.0	2.5	0.0	2.0	3.0
SIZE - area in ha	157	24	137	310	22	24	31	365	0	617	0	60	20
Percentage of total	8.9%	1.4%	7.7%	17.5%	1.2%	1.4%	1.7%	20.7%	0.0%	34.9%	0.0%	3.4%	1.1%

2048 Expanded Agroforestry													
ECOLOGICAL ASSETS	Settlements	Wetlands	Orchards	Agroforestry	Waterbodies	Major rivers	Minor rivers	Terraced croplands	Grasslands	Forests	Fallow lands	Shrublands	Plantations
CONDITION - score relative to its potential	3.0	2.0	3.5	3.5	1.0	1.0	3.0	3.5	0.0	2.5	0.0	2.0	3.0
SIZE - area in ha	157	24	137	497	22	24	31	178	0	617	0	60	20
Percentage of total	8.9%	1.4%	7.7%	28.1%	1.2%	1.4%	1.7%	10.1%	0.0%	34.9%	0.0%	3.4%	1.1%

Table 3: Changes to the size and condition of habitat types in different scenarios

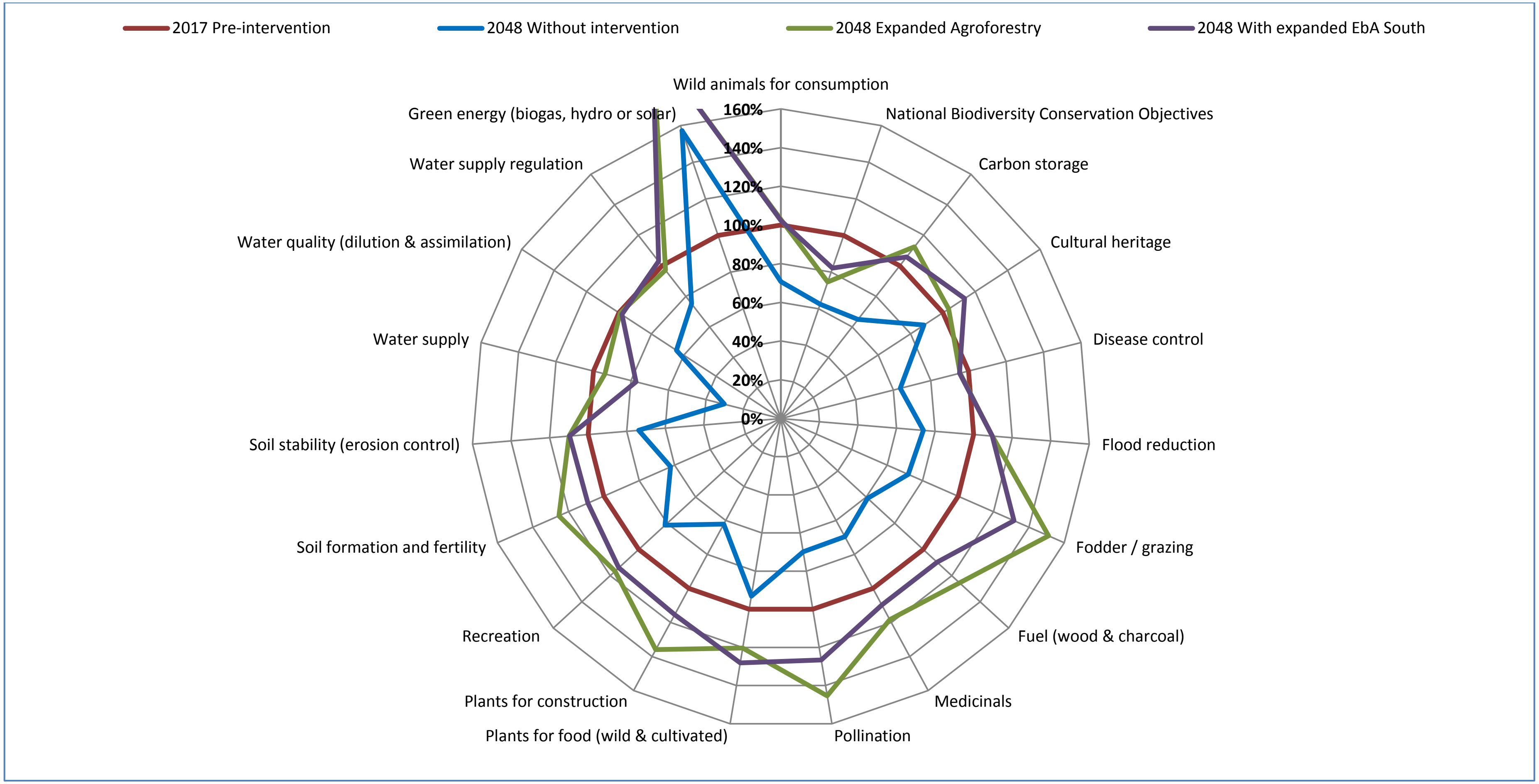


Figure 6: Changes to ecosystem services in future scenarios (the red line is the current level - with all services normalised to 100%)

8 THE IMPACT OF CLIMATE CHANGE RESPONSES TO SOCIETAL RISKS

The objective of climate change adaption actions is to increase the resilience of both the social and ecological systems in a society, and this implies understanding the risks facing the society. In the Chiti community, the key risks are[8]:

- Landslides
- Slope failures
- Greater intensity of rainfall events[9], with a possible 35% to 52% increase in intensity of single events
- Prolonged dry periods
- A decline in water availability associated with drier periods
- The dry season is projected to be drier
- The monsoon season is projected to get wetter
- Glacial melt projected to increase

[8] Climate Risk Profile: Nepal. https://www.climatelinks.org/sites/default/files/asset/document/2017_USAID%20CCIS_Climate%20Risk%20Profile_Nepal.pdf
[9] The intensity of rain is measured in the height of the water layer covering the ground in a fixed period of time.

In this analysis, the risk to ecosystem services in different scenarios is shown by a risk index, where Risk Index = demand/supply[10]. The risk associated with each ecosystem service in each scenario is illustrated in Figure 7 and Figure 8. There are three discrete levels of risk evident at Chiti, and include national level risks, district level risks and local level risks. The likely impacts of the EbA South climate change responses (assuming a landscape level programme in the future) to the different levels of risk are outlined below:

- National benefits at risk
    - The biodiversity conservation services are at risk, but the EbA South interventions will do little to reduce this risk in the future as most of the interventions focus on croplands, and forests require protection, which is not a focus on this initiative. This is a potential gap in the Chiti intervention package.
- District benefits at risk
    - The green energy services show the greatest level of risk in this analysis, generated by a large district and local user population highly dependent on the energy services. This risk could increase in the future by some 38% if Chiti transforms without climate change interventions. Note that the upstream impacts of climate change in the Marshyangdi catchment dominate these risks. However, degradation of the dam basin (that includes the Chiti area) could have significant and immediate negative consequences for the dam and hydro-electric scheme as there are no buffers between the Chiti landscape and the dam. Good basin management is critical to reduce risks, and the 38% elevation in risk noted above, highlights the critical role which EbA activities could play in reducing risk to green energy generation.
- Local benefits at risk
    - At the local level (see Figure 7 and Figure 8) the services at greatest risk are water supply, soil stability, food, plants for construction, water quality and water supply regulation. The risk indices of these services in the 2048 With Expanded Intervention and 2048 Expanded Agroforestry scenarios, show a significant reduction when compared to the No Intervention scenario, indicating the ability of these EbA interventions to promote resilience despite a possible doubling of the population. For example, the risk index of water supply is reduced by some 60% compared to a No Intervention scenario. Clearly, local society is likely to be much better off if EbA South interventions implemented and upscaled. A possible strategy to enhance water supply, water supply regulation and water quality would be to have a focus on stream bank restoration. This would include the removal of invasive plant species and to restoration of native species along minor rivers and stream banks. Furthermore, there is currently an emerging alien plant invasion in adjacent areas by *Chromoleana ordorata*, a highly invasive South American species, which has caused large scale loss of productive land in West and Southern Africa. It is likely that this species will invade the Chiti area and generate serious costs for the Chiti community. The EbA programme could place an additional focus on preventing this species invading the Chiti ward.

[10] Risk is a function of a combination of the demand and supply levels. In this analysis, the formula [Risk = Human Benefit Index / service supply index] is used, or in other words, how many demand units are there for each service supply unit available. Both the human benefit index and service supply index are computed in this analysis.

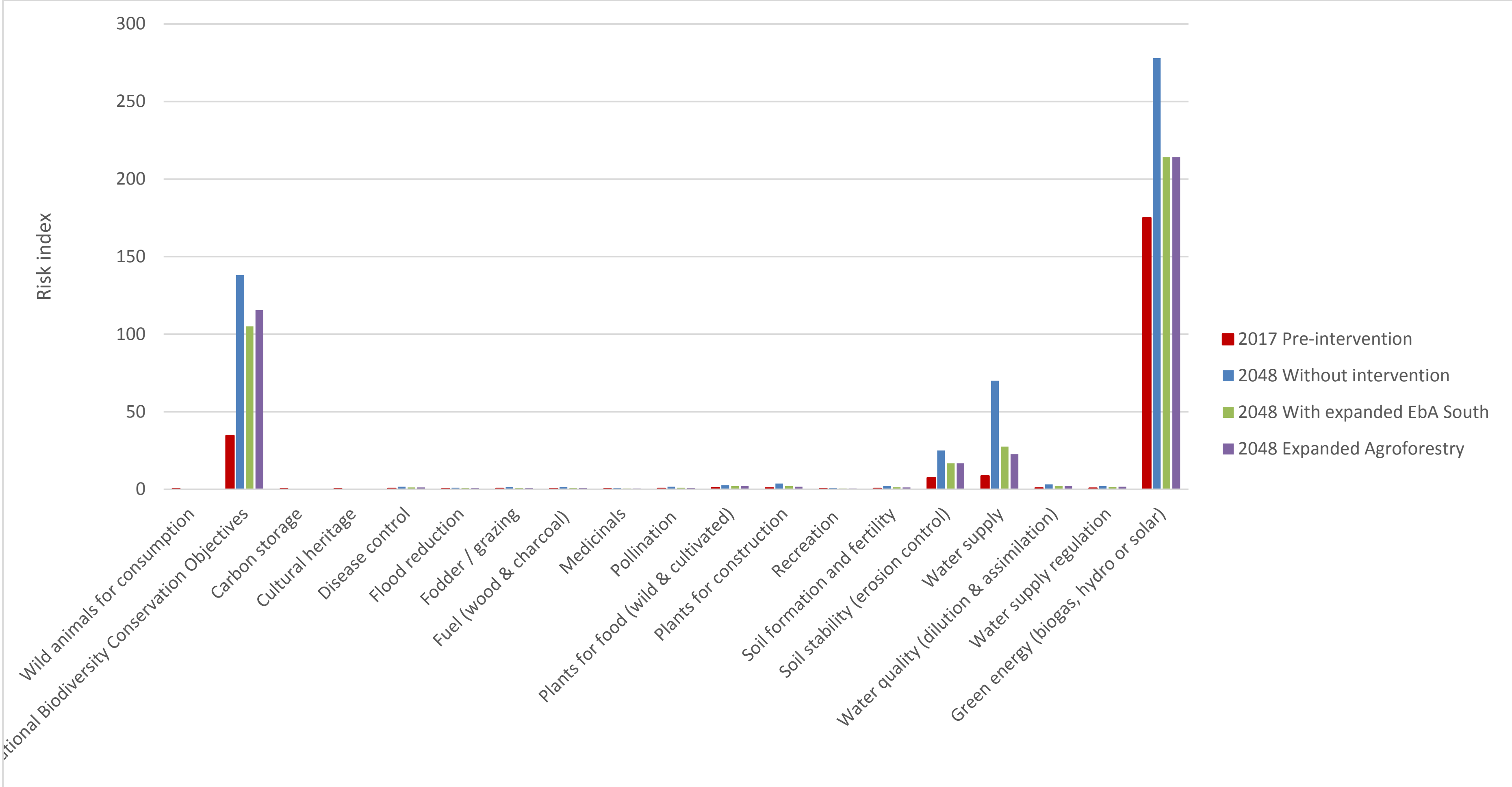


Figure 7: Changes in the relative risk levels in the adaptation scenarios

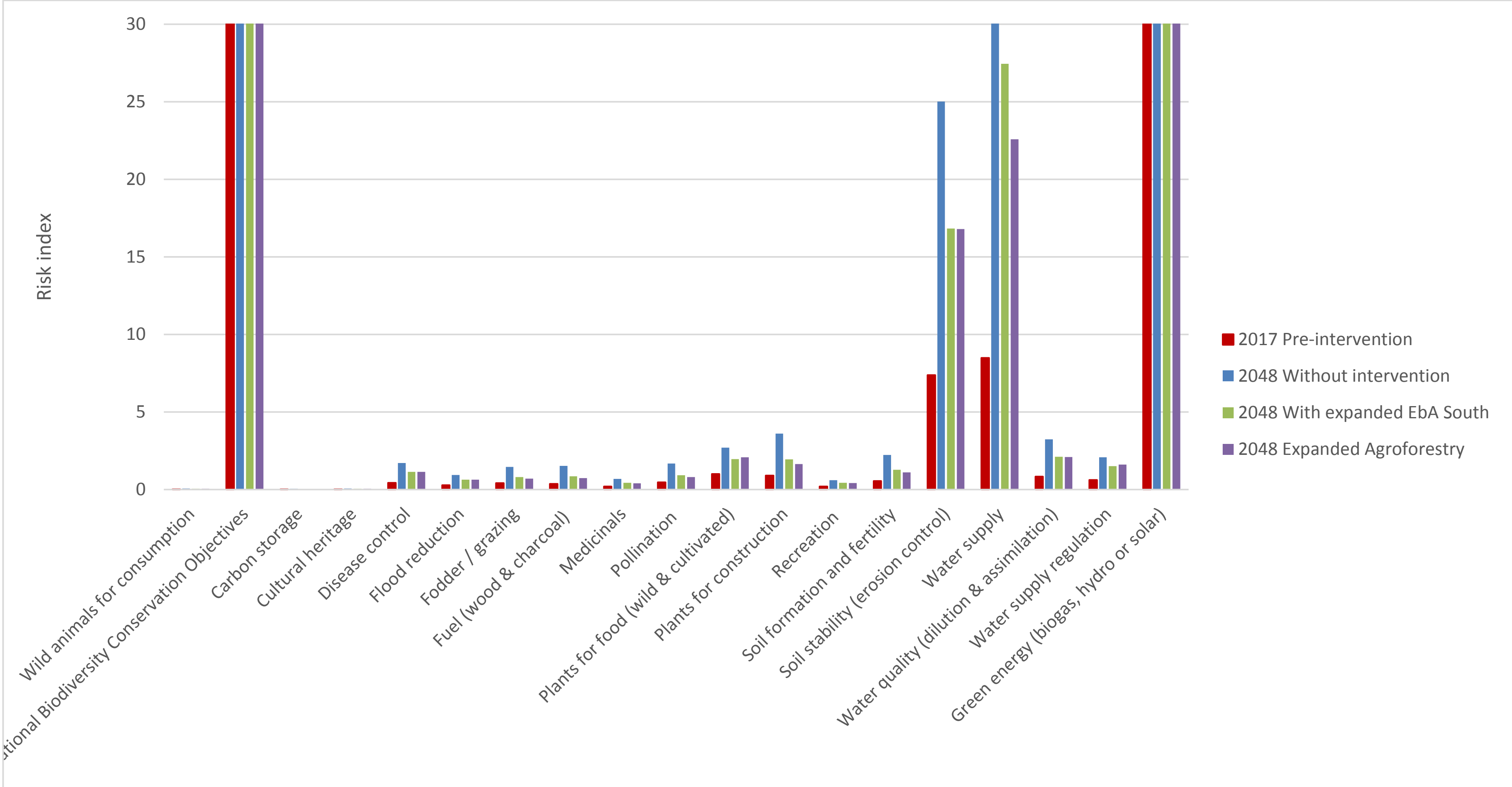


Figure 8: Changes in the relative risk levels in the adaptation scenarios - with the risk index axis limited to 30 to highlight local level risk

9 THE COSTS AND BENEFITS OF CLIMATE CHANGE INTERVENTIONS

A Cost Benefit Analysis (CBA) was undertaken to illustrate the costs and the associated benefits of the EbA South interventions in Chiti and would be useful for informing the future approach to such interventions.

The EbA South interventions at Chiti were undertaken across some 1767 hectares. The footprint of the interventions was relatively small and should be considered as series of small-scale experimental or pilot interventions. To assess the impact of the interventions, it has been necessary to virtually upscale the interventions, from an existing pilot project to a scenario of an expanded comprehensive programme, that would allow the impacts on ecosystem services to be observed and modelled. Consequently, this analysis follows the ecosystem services modelling approach in the previous sections and has adopted the scenarios developed in the previous section. The cost benefit analysis did not have resources to undertake any primary research, and consequently focused on using currently available information. As the intervention costs were the most reliable data available, these costs where used as the baseline and the benefits were calculated as a unit of cost.

In summary, the approach generated costs per hectare and then upscaled these costs as per the scenarios. In terms of the benefits, the CBA approach adopts a Human Benefit Index[11] as a measure of benefit and not the conventional monetary value. The advantage of using this metric is that many ecosystem services are not traded and consequently have no measured monetary value in the Chiti area. Without resources for a contingent valuation process[12] and to avoid giving these services a zero value, the Human Benefit Index is used in the CBA. In other words, how much human benefit is generated by US$1 spent? In this analysis, the Human Benefit Index is used to show the benefits in terms of the numbers of service users and intensity of service use, resulting from the EbA South intervention. Even though an index is used, this analysis is a good indicator of the level of benefit supplied as it correlates to locally specific wellbeing or the local level of consumption of services. The human benefit index used is the index calculated by the Ecosystem Services workshop with the Nepalese team (see chapter 6).

9.1 The parameters and model used

An Excel spreadsheet was developed to calculate the benefit cost values and ratios for different climate change response scenarios. The spreadsheet model is supplied with this report and can be used for further analysis or can be adapted for application in other sites. The detailed workings of the spreadsheet are not described in this report but are annotated or evident in the spreadsheet. The following parameters are built into the CBA model:

- Three climate change response scenarios have been modelled.
- Duration of the intervention. A 30-year timeframe has been used in the analysis.
- Note that these estimates are a partial estimate, as the income generated by the crops is not included. This is because intervention costs may then become 'negative costs' and make for a very confusing model.
- The social discount rate. Two options are provided, a pessimistic outlook (using 16%) or an optimistic outlook (using 8% (https://www.photius.com/rankings/2017/economy/central_bank_discount_rate_2017_1.html)). This analysis has used an optimistic outlook to discount the future values.

[11] Cartwright, A., Blignaut, J., De Wit, M., Goldberg, K., Mander, M., O'Donoghue, S. and Roberts, D. 2013. Economics of climate change adaptation at the local scale under conditions of uncertainty and resource constraints: the case of Durban, South Africa. Environment and Urbanization. https://doi.org/10.1177%2F0956247813477814

[12] Contingent valuation methods typically rely on surveys to assess the population's willingness to pay for given ecosystem services.

- Six interventions were modelled, including cardamom crop establishment, fallows revegetation, forest enrichment, cropland conversion to agroforestry, and orchard planting.
- The costs of each intervention were captured in terms of capital costs (establishment costs using the EbA South project costs) and annual operating costs (estimated maintenance costs). These costs have been provided by the EbA South project and Government of Nepal. An average cost was used for the different species used in each intervention. The average cost was then converted to a cost per hectare for each of the interventions, that is, the cost of specific EbA intervention (such as fallows regeneration) divided by the total area where the intervention occurred. For the future scenarios, these costs per hectare where then upscaled using the specific areas estimated or projected in each discrete intervention in each unique scenario.
- As it was necessary to have a cost estimate to make comparisons, the no intervention scenario used the opportunity cost of not implementing an upscaled EbA South programme. In the no intervention scenario, the opportunity cost was calculated as the decline in Chiti GDP per capita due to a decline in local ecosystem services. As most of the Chiti GDP per capita is based on natural resource use (agriculture, forest harvesting and river water use) we have assumed that the average decline in services per scenario, as modelled in Chapter 7, is a fair indicator or proxy for a likely decline in household wealth. The monetary value of the service decline, as a function of the GDP per capita, is used in the CBA.
- The present value of interventions and opportunity costs have been calculated using monetary costs, a time period (30 years) and a social discount rate of 8% (i.e. Nepal's National Treasury discount rate).
- The changes in ecosystem service supply levels (as a %) in each scenario are assumed to reduce the human benefit index by the same percentage. This may not always reflect reality but is used in this analysis as a 'best available proxy' in the absence of scientifically-proven relationships for each service in Chiti.
- The CBA model totals the costs for 30 years (in each scenario) and then discounts them using the social discount rate. Similarly, the model totals the Human Benefit Index over 30 years. These benefits have not been discounted as we assume the value to humans in the future will be as valuable as the present.
- The costs and benefits have been compared in various ways by the model.

9.2 The benefit cost model results

The CBA model outcomes are outlined in Table 4 below. Note the following in the table below:

- Present costs
  - A nominal value of $1 (and when discounted is 0.93c) is used for the pre-intervention scenario to have a non-zero value in the model otherwise a division by zero error occurs.
  - The opportunity cost of doing nothing (the Without intervention scenario) would be more than double the cost of an expanded EbA South programme.
- Quantity of human benefit units
  - Note that all the future scenarios anticipated a doubling of the Chiti population in 30 years due to climate change induced migration out of the high-altitude settlements. This implies that for the Without intervention scenario, where the benefit index is less that the present situation, fewer benefits would have to be shared double the people. In other words, there are fewer benefits per capita.
  - The benefits increase in the two intervention scenarios, from an index of around 14 million to approximately 20 million.
- Human benefits per capita per year
  - As an index, the current population of Chiti enjoys on average some 103 benefit units per year using different services. This declines in all three future scenarios, with the Without intervention scenario showing the most serious decline due to the combination of both a service level reduction and a population increase. In the expanded EbA South scenario and the expanded Agroforestry scenario, the services available per capita are also likely to decline but less so. A doubling of the population would neutralise the service supply increases.
    - The implication is that the Chiti landscape is unlikely to be able to support a growing population. Additional ecological interventions will be necessary but not sufficient to sustain household well-being. Social solutions, including urban densification, urban migration, forest management and river management, will need to be part of the solution.
- Effective US$ per capita with respect to the value of the benefits
  - Given the GDP per capita of Chiti (US$1 186) per year (365 days), this implies local residents benefit with US$3.25 per day. Using the above changes in service levels and its associated impact on wellbeing and correlating these benefits to the daily per capita value as an indicator, the local residents could see their benefit value of$3.25 per day being reduced in future scenarios to $1.47, $2.04 and $2.01 respectively. Note these estimates are averages. While all households will experience losses related to declines in forest, wetland and river ecological functionality, those households with farms are likely to fair better as food production services decline by less than the average decline in services.
    - The implication is that a Without intervention scenario will essentially halve the local benefits as the natural resources decline and the population doubles in the future.
    - The differences in resource ownership implies there is likely to be greater social conflict in the community with have's and have nots.
- Number of human benefit units relative to 2048 Without intervention
  - In terms of a Without intervention scenario, an expanded EbA scenario could lead to 39% more human benefit and an Expanded Agroforestry scenario could lead to 36%more human benefit.
- Human benefit units per US$
  - In the Without intervention scenario US$1 spent (on growing agroforestry) or losses incurred (opportunity cost of lost wealth), results in 6.93 human benefit units.

- In the With expanded EbA intervention scenario, US$1 spent buys 21.39 units of human benefit.
    - This implies a US$1 spend buys 209% (or 3 times) more benefits than a Without intervention scenario.
- In the expanded agroforestry scenario a US$1 spend buys 15.41 units of benefit.
    - This implies a US$1 spend buys 122% (2.2 times) more benefits than a no intervention scenario.

Table 4: Comparison of costs and benefits of the future scenarios over 30 years

	2017 Pre-intervention	2048 Without intervention	2048 With expanded EbA South	2048 Expanded Agroforestry
Chiti Population (current and future scenarios)	5 166[13]	10 332	10 332	10 332
GDP per capita (2017)	1 186[14]	1 186	1 186	1 186
PV of costs: US$	0.93	1 927 130	866 897	1 181 973
Costs relative to 2017 Pre-intervention – as a factor	1	2 081 301	936 249	1 276 531
Quantity of human benefit units (over 30 years)	15 921 276	14 426 620	20 025 004	19 671 381
Number of human benefit units/capita/yr	103	47	65	63
Effective US$/capita with respect to the value of the benefits	3.25	1.47	2.04	2.01
Number of human benefit units relative to 2048 Without intervention	1.10	1.00	1.39	1.36
Human benefit units per $		6.93	21.39	15.41

In summary, an expanded EbA South programme at Chiti would be the most effective ecological intervention for maintaining human benefits. However, this action will not be sufficient to sustain human benefits if the population grows significantly in Chiti. Indeed, if the project generates considerably greater wellbeing, it may attract more people into the area and dilute the intended benefits. The project could become a victim of its own success. Clearly a social intervention needs to be combined with the ecological intervention to sustain the intended benefit gains. These social interventions may include:

- supporting better urban development and management,
- promoting better land rights,
- promoting better management of common property resources (such as forests and rivers), and
- promoting beneficiation of local resources, such as grains, fruits and dairy to provide alternative incomes to resource use.

13 National Population Report 2017. Ministry of Population and Environment (MoPE). Singha Durbar, Kathmandu.

14 www.Nepalmap.org/profiles/district-37-lamjung

10 CONCLUSIONS

10.1 The supply of ecosystem services

- There are strong hydrological linkages between the different habitat types, such as forests and minor rivers, or terraced croplands and minor rivers. The implication is that intervening in terrestrial landscapes needs to be informed by careful consideration of the direct and indirect impacts of run-off, water flows, pathogen flows and sediment flows.
- Much of the natural capital is in poor to moderate condition. This implies that the current social-ecological system is unlikely to be resilient to future climate change perturbations, such as high intensity rainfall events, prolonged dry periods, high temperatures, slope failures and flooding. The condition of the habitats implies that much can be done to promote resilience to climate change by improving the condition of the natural capital stock (such as forests and rivers), thereby increasing functionality and elevating service supply levels.
- The natural capital in Chiti ward currently plays and can continue to play, an important role in mitigating the impacts of climate change in Nepalese society, which includes:
    - Protecting built infrastructure such as roads, buildings and hydro-electric infrastructure, from extreme rainfall events, usually accompanied by landslides, flooding and sedimentation. Protecting productive land such as terraced croplands, orchards, plantations and agroforestry from slope failures and sedimentation.
    - Enhancing productive landscapes such as croplands, orchards and agroforestry by elevating soil moisture, carbon storage and soil fertility. Elevating soil moisture is critical for maintaining production in dry periods or droughts associated with climate change.
    - Promoting water security by providing access to adequate quantities of water, by regulating flows and providing access to dry season water, and by ecosystems reducing pathogens in water. Maintaining adequate flows in climate change induced prolonged dry periods or droughts, is critical for human health and welfare in terms of having access to water for consumption and production. Importantly, adequate water volumes or flows are critical for maintaining the dilution and assimilation services of rivers, streams and dams, which render pollution relatively safe. Water security for production purposes also secures livelihoods, by sustaining income earning opportunities, in episodic climate extremes.
    - The wide range of goods and services supplied by the Chiti environment promotes resilient economic activities by allowing a diverse range of economic activities to be undertaken, thereby insuring against events which may threaten a single activity such as rice production.
- The ongoing conversion of natural capital, over-use (harvesting) of ecosystems, increasing pollution discharge, infestation by alien species and water flow disruptions (alien plant evapotranspiration, accelerated runoff, abstraction and diversion) are currently running down the terrestrial and freshwater natural capital in Chiti. This may be further exacerbated by climate change. The implication is that ecosystems need to be made more resilient to cope with bio-physical disruptions, such as climate change events. The failure to generate resilient ecological systems, will imply that currently available natural capital services will need to be replaced by built capital services, using scarce financial capital. It is unlikely that this strategy will be affordable in Nepal (and in fact in most countries), and consequently maintenance of existing ecological infrastructure (through actions such as the EbA South interventions) will be the cheapest option available to Nepalese society.

10.2 The demand for ecosystem services

- The Nepalese Government should identify which climate change responses will offer the greatest net benefit to society. In other words, which action will offer the greatest level of benefits per Rupee spent. For example, forests in Chiti are major generators of: i) conservation services (which benefit the nation), ii) erosion control (which benefit the district population in terms of energy security) and iii) water supply regulation, water quality, energy, construction materials, pollination and flood reduction (all of which are critical for local households). An intervention which promotes forest functionality is likely to offer Nepalese society the greatest package of services and benefits and can be considered a No Regrets Approach which generates good benefits with or without climate change.

- The second most useful intervention is likely to be management of paddy fields which offer district and local benefits (and may be more politically attractive).
- Focussing interventions on single user groups, such as food producers, is likely to produce suboptimal outcomes in terms of human wellbeing and economic benefits.

10.3 The intervention scenarios

- **2048 Without the Intervention Scenario** – The consequences of a no intervention scenario are a significant reduction in most of the ecosystem service levels, with service level declines of between 20% to 60%. Water supply suffering the greatest reduction in supply. In this scenario there will be double the population and far fewer services, with a consequent decline in services per capita. Much of the decline is due to a combination of increased human pressure, land transformation and climate change.
- **2028 With Expanded EbA South Scenario** – in this scenario, the EbA South project interventions include planting high value tree species in fallow lands, converting marginal rice croplands to agroforestry, enrichment planting in degraded shrublands, enrichment planting in forests, promotion of energy efficient stoves and lights) and diversifying income earning potential by making high value fruit and bee products accessible. The 2048 With Expanded EbA South scenario accounts for climate change, population growth, settlement growth *and* expanded EbA interventions. Note that in this scenario, the current suite of EbA South project interventions is upscaled significantly to evaluate its impacts at a landscape level. In this scenario croplands, fallow lands, shrublands and grasslands decline but are replaced with well managed high value crops such as fruit orchards and agroforestry. The implications for ecosystem services is a modest expansion in most services, with biomass energy, food crops, fodder and pollination growing the most. On the other hand, water quantity supplied and national biodiversity conservation services contract. Importantly, despite double the population, water supply regulation and water quality are maintained.
- **2048 Expanded Agroforestry Scenario** – this scenario is similar to the 2048 With Expanded EbA South scenario, except that much of the terraced croplands are converted to agroforestry. In this scenario the relatively low value rice production is replaced by higher value agroforestry fruit, fodder, fuel and legume food crops. The greatest benefit of this scenario is elevated ground cover and greater biomass, resulting in stable and more fertile soils, greater fuel, fodder, medicinals, construction materials and pollination, but with slightly less food. Importantly, the elevated ground cover reduces run-off, erosion and sedimentation, resulting in improved water quality services and elevated minor rivers conditions.

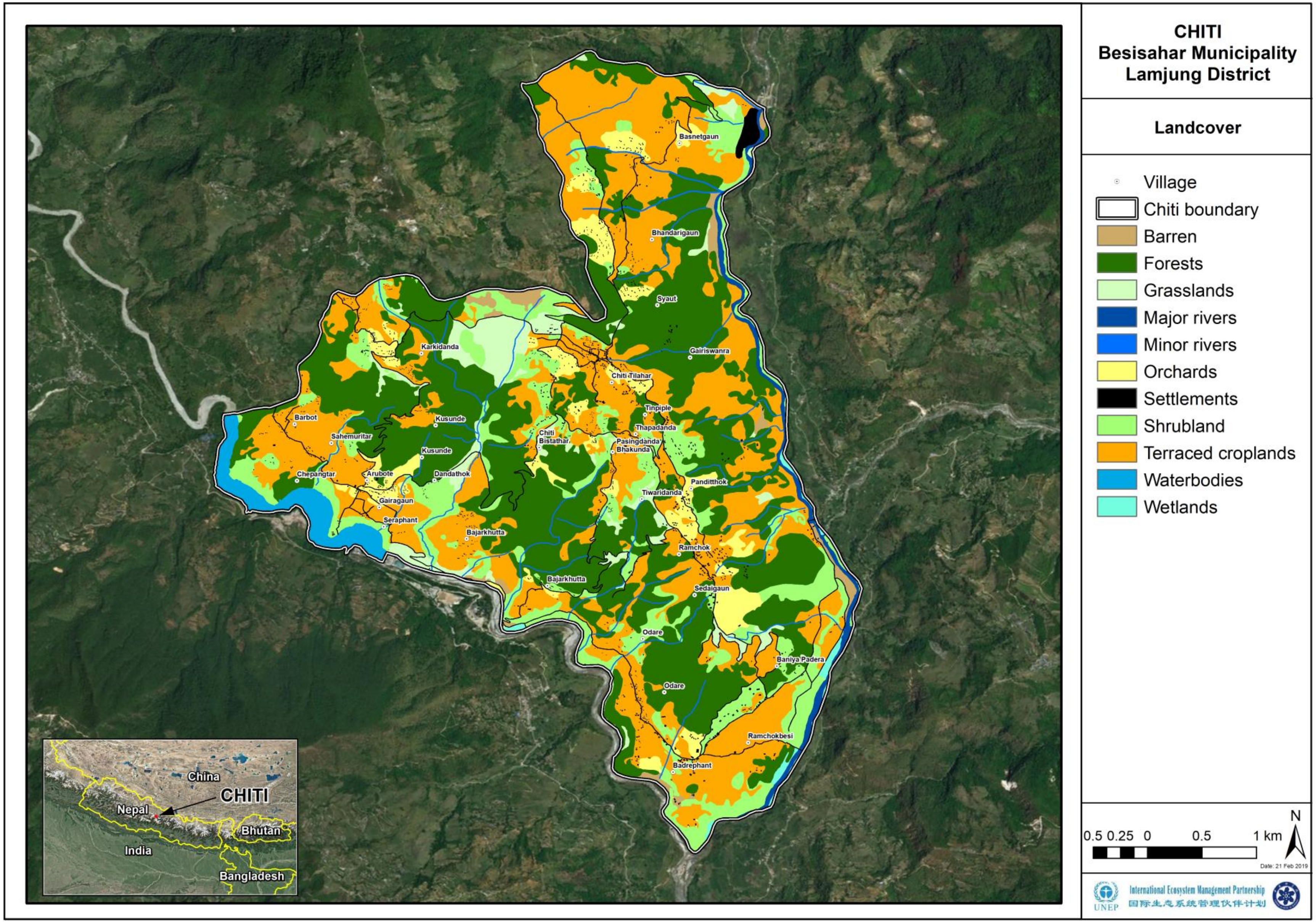
10.4 The costs and benefits of climate change interventions

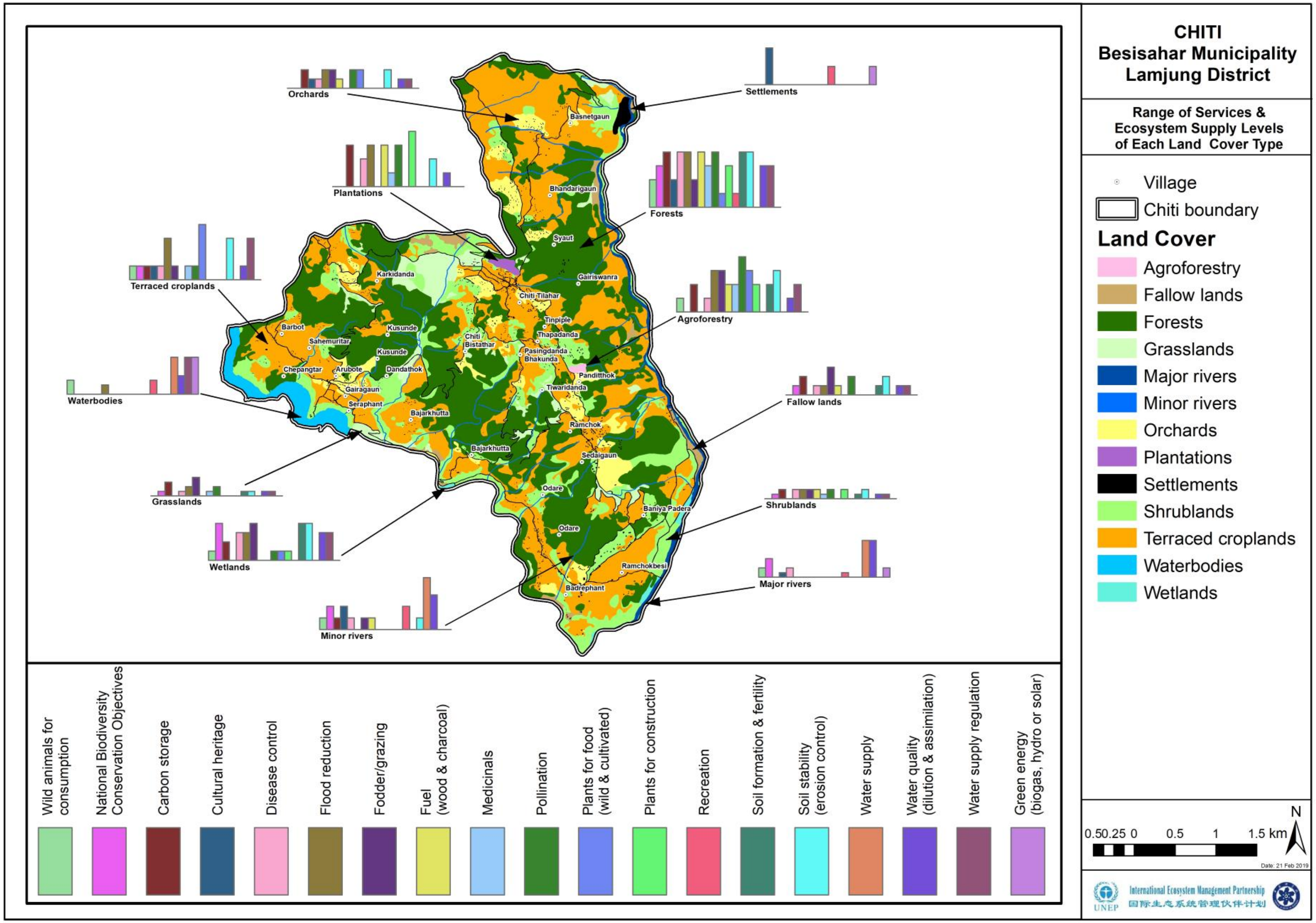
In summary, an expanded EbA South programme at Chiti would be the most effective ecological intervention for maintaining human wellbeing. In the Without intervention scenario, US$1 spent (on growing agroforestry) or loss incurred (the opportunity cost of lost wealth), results in 6.93 units of human benefit. In the With expanded EbA intervention scenario, US$1 buys 21.39 units of human benefit. This implies US$1 buys 209% (or 3 times) more wellbeing than a Without intervention scenario. In the Expanded Agroforestry scenario, US$1 buys 15.41 units of wellbeing. This implies US$1 buys 122% (2.2 times) more wellbeing than a Without intervention scenario.

However, this action will not be sufficient to sustain human wellbeing if the population grows significantly in Chiti. Indeed, if the project generates considerably greater wellbeing than other settlements (especially higher-altitude settlements), it may attract more in-migration and dilute the intended benefits. Clearly, social interventions need to be combined with the ecological interventions to sustain the intended benefits. These social interventions may include:

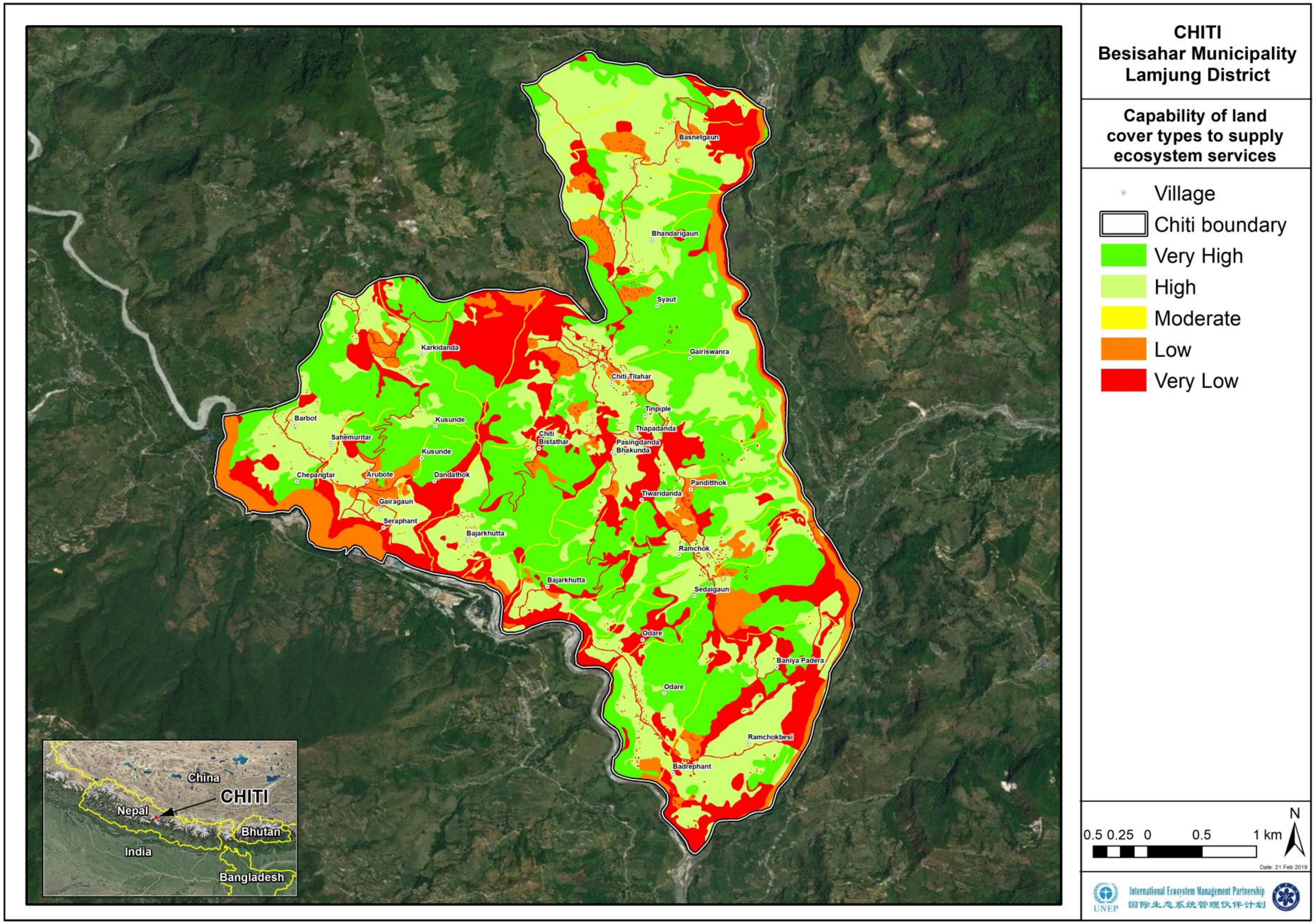
- supporting better urban development and management in neighbouring areas,
- promoting better land rights at Chiti,
- promoting better management of common property resources (such as forests and rivers) in Chiti, and
- promoting beneficiation of local resources, such as grains, fruits and dairy in Chiti and neighbouring areas.

APPENDIX 1: LOCALITY MAP OF THE LANDSCAPE SHOWING BOUNDARIES AND KEY LAND COVER TYPES




CHITI
Besisahar Municipality
Lamjung District
Range of Services & Ecosystem Supply Levels of Each Land Cover Type
Village
Chiti boundary
Land Cover
Agroforestry
Fallow lands
Forests
Grasslands
Major rivers
Minor rivers
Orchards
Plantations
Settlements
Shrublands
Terraced croplands
Waterbodies
Wetlands
Orchards
Settlements
Plantations
Forests
Terraced croplands
Agroforestry
Waterbodies
Fallow lands
Grasslands
Shrublands
Wetlands
Major rivers
Minor rivers
Basnetgaun
Bhandarigaun
Syaut
Gairiswanra
Karkidanda
Chiti Tilahar
Tinpiple
Thapadanda
Barbot
Kusunde
Sahemuritar
Chiti Bistathar
Pasingdanda
Bhakunda
Chepangtar
Arubote
Dandathok
Pandithok
Gairagaun
Tiwaridanda
Seraphant
Bajarkhutta
Ramchok
Sedaigaun
Odare
Baniya Padera
Ramchokbesi
Badrephant
Wild animals for consumption
National Biodiversity Conservation Objectives
Carbon storage
Cultural heritage
Disease control
Flood reduction
Fodder/grazing
Fuel (wood & charcoal)
Medicinals
Pollination
Plants for food (wild & cultivated)
Plants for construction
Recreation
Soil formation & fertility
Soil stability (erosion control)
Water supply
Water quality (dilution & assimilation)
Water supply regulation
Green energy (biogas, hydro or solar)
N
0.50.25 0 0.5 1 1.5 km
Date: 21 Feb 2019
UNEP
International Ecosystem Management Partnership

APPENDIX 3: MAP SHOWING THE AREAS OF HIGH TO LOW SERVICE SUPPLY LEVELS



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Enhancing Capacity, Knowledge and Technology Support to Build Climate Resilience of Vulnerable Developing Countries