Review of Evidence: Asia Pacific Regional Climate Resilience Platform

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Executive summary

There is a large and growing body of research which validates the need for an urgent scaling-up of action on climate change in Asia. This includes evidence of the short- and medium-term impacts of climate change on economic output, development and poverty reduction in Asia, as well as the synergies and trade-offs between adaptation to climate change and biodiversity conservation.

There is considerable global research on the conceptual interactions between both climate change adaptation and mitigation and the Sustainable Development Goals (SDGs). Documented experiences in Asia also affirms the strong synergies between climate actions and not just SDG 13 (climate change) but also SDGs 2 (zero hunger), 6 (clean water and sanitation) and 8 (decent work and economic growth) among others. For example, research on climate smart agriculture practices in Asia indicates development benefits including increased incomes, enhanced food security and reduced gender inequality. Other examples of synergies include increased school enrolment from disaster risk reduction measures and improved human health from low-emission sources of electricity.

There is also considerable research on the potential trade-offs between climate actions and other SDGs. A number of SDGs, particularly those relying on economic growth, infrastructure development and an increase in energy production, could challenge climate change mitigation objectives unless there is also a corresponding rapid expansion in renewable energy. There are also potential trade-offs between action on climate change and other development benefits related to the use of land, for example potential conflict between the production of biofuels and food as well as the impact on ecosystems. Experiences from some REDD+ projects have also shown inequitable distribution of financial resources at local scales.

The research on potential conflicts between climate change and development objectives identifies risks that should be managed and monitored during the design and implementation of projects. For example, the potential trade-off of increased food production putting pressure on forest ecosystems could be reasonably mitigated by adopting agroforestry practices on a large scale or by improving agricultural yields and/or preserving forest ecosystems and biodiversity. Similarly, increased energy use to produce food for growing populations could be offset by the adoption of climate smart agriculture practices, which can be far more resource efficient than traditional agricultural methods. In some cases, 'win-win' scenarios are not possible, and in that case a careful consideration of options that do the least harm is required.

There is a substantial evidence base on the disproportionate economic impacts of climate change in Asia, providing a strong economic rationale for enhanced climate action. There is consensus across different global studies that developing countries in Asia will witness higher costs from climate change to economic growth than other regions. One study estimates global losses being 4.4% of per capita GDP by 2100, while South Asia will witness losses of 15%, followed by South East Asia (13%), the Pacific (9.6%), and Central Asia (2.5%) (Lee et.al., 2016). Outside Asia, the Middle East and North Africa (MENA) and Sub-Saharan African regions account for the largest estimated climate-induced economic losses. Estimates show that developing countries in Africa would lose as much as 27% of their GDP by end of the century, in the absence of any mitigation effort (Kompas, Pham, & Che, 2018).

It is also widely acknowledged that these economic impacts are likely to be underestimates, particularly given the methodological challenge of capturing losses from extreme events. These estimates should therefore be considered along with literature on the cost of natural disasters and extreme events. Studies of average annual losses from natural disasters highlight that these losses are increasing in Asia and range widely from 10-76% of social expenditure of different countries (UN ESCAP, 2016). Of the countries studied, Bangladesh and the Philippines face particularly high losses from natural disasters. Droughts, tropical cyclones and floods account for the majority of the economic impacts (ibid).

There are significant methodological and practical issues with estimating the economic impacts of climate change and comparing results from different studies. The impacts are estimated using economic modelling and will vary depending on the assumptions applied about climate scenarios and other variables. For example, models assume that national commitments on emission reductions will be met, which may be unrealistic. Many studies use statistical analysis to understand future impacts from past climate trends, which assumes a static relationship between the climate and economy.

There are alternative measures to study socio-economic impacts of climate change, such as levels of inequality, health indicators and education attainment. For example, a 1% increase in climate risk exposure causes a widening of the Gini coefficient by 0.24, an increase of the under-five mortality rate by 0.3 and lowers education rates by 0.26% (UN-ESCAP, 2019). The impact of climate change on food production and food prices will increase the population living in extreme poverty by up to 67 million by 2030 (Hallegatte et.al., 2017). In Central Asia, it is estimated that the impact of climate change risks increasing social tensions particularly related to sharing rivers and reduced regional cooperation (Omelicheva, 2018). At the local level, estimating economic impacts is difficult, and other estimates such as number of people affected by natural disasters, indebtedness, and small business' profits are feasible.

Global rankings of countries' vulnerability to climate change are difficult to compare but provide some insights on the most vulnerable of those countries studied. There is considerable variation in the results and rankings of the 14 countries[1] studied in the four most available and quoted climate vulnerability rankings and indices: the Global Climate Risk Index (CRI), the Global Adaptation Index (GAIN), the Environmental Vulnerability Index (EVI), and the Climate Vulnerability Monitor (CVM). For example, Bhutan is ranked as relatively less vulnerable in the CRI and EVI rankings, but high in the GAIN ranking. Cambodia is ranked outside the top 100 most vulnerable countries in the CRI ranking, but with the highest level of classification of vulnerability in the CVM.

The considerable variety in the rankings of different countries in Asia can be explained by very different methodologies for each of the rankings. This includes the sample size (e.g. the EVI includes 239 countries, considerably more than others), how up to date the data is (e.g. the EVI uses older data from 2004), and, most significantly, the choice of indicators used to measure vulnerability. The methodological variation is fundamentally a result of a lack of global consensus on the definition of vulnerability to climate change and how to measure it, despite the considerable research attention it has received over the last decade.

[1] The target countries studied for this paper were: Bangladesh, Bhutan, India, Nepal, Pakistan, Kyrgyzstan, Tajikistan, Uzbekistan, Cambodia, Indonesia, Laos, Myanmar, Philippines and Vietnam.

Each of the four rankings has a different purpose: GAIN and EVI are more comprehensive and strongly grounded in scientific research and developed by leading academics, while CRI and CVM include less dimensions of climate vulnerability but receive more media attention due to their graphics and presentation. Between GAIN and EVI, the former is more regularly updated and as such presents perhaps the most useful measure and metric for tracking progress.

There is similarly a lack of consensus on measuring climate change resilience. There is no consistent definition of what constitutes resilience to climate change and what indicators can be used to measure progress. Resilience has been studied from the perspective of an ecosystem, a socio-ecological unit, society in general and a specific community. There are many suggested frameworks to define and measure progress. While these have some common features (for example, well-being, livelihood viability, access to contingency resources in the event of a disaster etc) there is also huge variability in what is included. For example, for some, sustainable management of agricultural land is a clear indicator of resilience, while for others, resilience is driven by governance and institutional changes.

In addition, most frameworks of resilience do not explicitly prescribe indicators, but suggest thematic areas and components for which indicators can be tailored based on the specific local context. Indicators should be used with care, partly because they are based upon assumptions and context-specific factors. For example: which types of crops offer the greatest resilience in a situation of drought, flood or heatwave? Should farmers be planting all of their fields or is it best to leave some fallow? Are more formal institutions better or worse than less formal ones in managing extreme events? In reality, these and other possible indicators need to be set at a project, programme or location specific setting. It may also be more appropriate to focus on measuring vulnerability to assess progress in the first instance, meaning changes in ability to meet basic needs, access to external resources, and ownership or control of (physical, economic, human, social, economic) assets.

Measuring biodiversity and progress in conservation efforts is similarly contested. Given the huge number and diversity of ecosystems and species, measuring changes quantitatively over time is very difficult. While there may be notable trends at a global or regional scale, changes at local scales may show large variation and no clear trend. There has been some effort to identify thresholds, and early warning indicators for an impending ecosystem regime shift. There are also qualitative approaches which provide a more nuanced study of the drivers of ecosystem degradation. There are a range of existing frameworks for measuring the resilience of ecosystems, primarily designed for a project or specific ecosystem unit. These can be adapted and expanded to suit the specific context and purpose under investigation.

There is considerable research on biodiversity hotspots in Asia, as well as the synergies and trade-offs between biodiversity conservation and climate resilience. Of the 36 most important global hotspots, seven are located in Asia (Mountains of Central Asia, Wallacea, Eastern Himalayas, Western Ghats, the Philippines; Sundaland and Nicobar Islands and Indo-Burma). These are regions which are irreplaceable and have at least 1,500 vascular plants as endemics and have at least 30% or less of its original natural vegetation. It has been estimated that a one-time cost of $25 billion could save all the global hotspots (Pimm et.al., 2001). There are different estimates of the socio-economic benefits of conserving these hotspots, but all are very large. A comprehensive global OECD (2019) study estimates that ecosystem services provide benefits of $125-140 trillion per year. Biodiversity is also considered essential for progress towards 80% of the assessed SDG targets related to poverty, hunger, heath, water, cities, climate, oceans and land (IPBES, 2019).

Asia has underperformed in achieving targets agreed by governments under the Convention for Biological Diversity (CBD). Some of the most direct drivers of degradation include illegal wildlife trade, deforestation and fragmentation of habitats, urbanisation and human intrusion. The evidence on impacts of climate change on biodiversity has grown stronger and the IPCC has become more confident in attributing the impacts of climate change at a species and ecosystem level. Research from the local level in Asia also documents the climate benefits from biodiversity measures. For example, mangrove and coastal biodiversity restoration not only improves the habitat for fish and bid species but also helps protect from floods and natural disasters. However, there are also trade-offs between climate adaptation and conservation measures that need to be managed, particularly related to land and water use.

Nature-based Solutions (NbS) is an umbrella term that has evolved since the early 2000s from a variety of disciplines and covers a range of actions that protect or restore ecosystems while providing a range of benefits. Ecosystem-based Adaptation (EbA) is a subset of many possible activities which specifically focus on providing adaptation to climate change (although many can also deliver climate mitigation benefits, such as deforestation activities). NbS feature prominently in Nationally Determined Contributions (NDCs): 85% of the NDCs have NbS featured either as a mitigation or adaptation strategy, or both (NbSI, 2020). The most commonly featured NbS in NDCs relate to forestry activities, coastal and marine habitats and river catchments (including wetlands) with only a few related to montane habitats, grasslands or rangelands. However, only around 17% of the NbS include quantifiable targets, considered a key risk to the implementation and tracking of progress (Seddon et al., 2019).

There is considerable evidence on the climate and development benefits of NbS and EbA, building on the literature on biodiversity conservation in general. A peer-reviewed study led by scientists from 16 institutions stated that natural climate solutions can deliver 37% of cost-effective carbon dioxide mitigation needed by 2030 for a greater than 66% chance of holding global warming below 2°C this century (Griscom et.al, 2017). Global studies have been substantiated by case studies across the world, for example, in Nepal, ecosystem-based bioengineering methods were used to reduce roadside landslide instabilities and shown to be cost-effective, locally adaptable and increase the resilience of local communities. However, there is no universal definition for ‘effective’ adaptation, much less an ‘effective’ NbS or EbA. Different solutions can be compared using different metrics, for example the biophysical effects, risk exposure and vulnerability, economic costs and benefits etc. While the literature indicates that they offer intrinsic potential benefits for climate change and development, their actual effectiveness depends on the local context and how they are implemented.

In conclusion, evidence from global research, together with case studies from Asia, suggest that an increased investment in resilience has the potential to deliver significant economic and development benefits. If NbS and EbA is specifically pursued, then it could also contribute to conserving some of the most biodiverse and degraded hotspots in the world. However, for many climate actions there are potential development and conservation trade-offs that need to be carefully assessed and managed. Lastly, the evidence does not provide a ready-made measurement framework or indicators for measuring progress on resilience, NbS or EbA. A bespoke set of metrics will need to be developed and aligned to the specific context and purpose of any new resilience programme.

Table of contents

List of tables, figures, and boxes

List of abbreviations

AAL	Average annual loss
ACT	Action on Climate Today
AR1	First Assessment Report
AR4	Fourth Assessment Report
AR5	Fifth Assessment Report
BAU	Business as usual
CBD	Convention on Biological Diversity
CEPF	Critical Ecosystem Partnership Fund
CI	Conservation International
CRI	Climate Risk Index
CSA	Climate-smart agriculture
CVM	Climate Vulnerability Monitor
DRR	Disaster risk reduction
EbA	Ecosystem based adaptation
EVI	Environmental Vulnerability Index
FDP	Fertilizer deep placement
GAIN	Global Adaptation Index
GDP	Gross domestic product
GHG	Greenhouse gas
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
NbS	Nature based solutions
NBSAP	National Biodiversity Strategy and Action Plan
NDC	Nationally determined contributions
NTFP	Non timber forest products
OPM	Oxford Policy Management
PAME	Protected Area Management Effectiveness database
PPP	Purchasing power parity
SDG	Sustainable Development Goal
SIP	Sustainable intensification for paddy
SME	Small and medium enterprise
UNODC	United Nations Office on Drugs and Crime
WWF	World Wide Fund for Nature

1 Introduction

This report reviews, critically evaluates and presents available evidence relevant to the design of the 'Asia Pacific Regional Climate Resilience Platform'. It is intended to support DFID's Asia Regional Team in the design and development of the platform and directly inform the Business Case.

The scope of the research review includes available evidence on the following:

1) Evidence on the short and medium term impacts of climate change on economic output, development and poverty reduction in the region. This includes:
   - Analysis of specific linkages, trade-offs and synergies between climate action and SDGs
   - Estimates of economic and social costs of climate change and climate action, including responses to recent extreme events
   - Ranking of countries in terms of key indicators of climate vulnerability
2) Evidence on the linkages between climate resilience and broader environmental sustainability, with a particular focus on biodiversity and ecosystem services, and potential to deliver address both objectives through the platform. This includes:
   - Identification of relevant metrics and descriptors
   - Mapping of biodiversity "hotspots" in Asia, rates of degradation and key drivers
   - Analysis of specific synergies/ trade-offs between biodiversity conservation / ecosystem protection and climate resilience
   - Evidence on the potential, and cost-effectiveness of "nature based solutions (NbS)" or "ecosystem-based adaptation (EbA)" in delivering both climate resilience and biodiversity benefits, priority areas within NbS/ EbA and their inclusion in national climate (and other relevant) strategies and plans

The geographic scope of the evidence review includes: global and regional literature relevant for South Asia, Central Asia, Southeast Asia and to a lesser priority, the Pacific region. It also targets national case studies from the following countries: Bangladesh, Bhutan, India, Nepal, Pakistan, Kyrgyzstan, Tajikistan, Uzbekistan, Cambodia, Indonesia, Laos, Myanmar, Philippines, Vietnam.

The review intends to present the available literature, but also assess the breadth and depth of evidence available on the different research questions. This includes noting methodological variances, limitations in the analysis and identifying any research gaps. Only research findings which are considered robust, meaning from a peer-reviewed source and is validated by a number of different sources, have been included.

The evidence review process was a primarily desk-based exercise. As an initial step, a detailed set of research questions were agreed for each area of interest, and sources of literature were documented in a database. A peer review process was used to validate the analysis, particularly the critical evaluation of the literature presented.

2 Linkages, trade-offs and synergies between climate action and SDGs

There is a considerable amount of literature pointing to the importance of understanding the interactions between climate action and the Sustainable Development Goals (SDGs). In many instances these interactions are intuitively synergistic—for example, between national level renewable energy policies and SDGs 13 (climate change), 7 (affordable and clean energy), and 3 (good health and well-being). In other instances, possibilities exist for negative interactions as well, where successful climate actions counteract desired SDG impacts. These trade-offs have been recognised in IPCC assessment reports and have been examined at the SDG target level in peer reviewed research.

Research looking at specific climate actions in Asia agrees with the global evidence, finding significant interactions not only with SDG 13 (climate action) but also SDGs 2, 6, and 8 (zero hunger, clean water and sanitation, decent work and economic growth) among others. For example, climate smart agriculture is being practiced to great effect in flood prone regions of Southeast Asia, and agroforestry is providing demonstrated benefits in Central Asia.

However, while there is great potential for well-designed and implemented climate actions to have strong synergies with multiple SDGs, a number of trade-offs are possible, particularly if not carefully considered during programme design. A number of SDGs will naturally require increased energy consumption to achieve them—particularly 3 (good health and well-being) and 8 (economic growth)—which may conflict with climate mitigation objectives unless there is a rapid expansion of renewable sources of energy. Similarly, shifting to biofuels (as a net zero emissions strategy) can put pressure on food production and land-based ecosystems.

Many of the trade-offs have potentially severe implications on achieving the SDGs, however there is scope for trade-offs in some areas to be mitigated by synergies in others. For example, the potential trade-off of increased food production putting pressure on forest ecosystems can be reasonably mitigated by adopting agroforestry practices on a large scale or by improving agricultural yields (thus requiring less land area per calorie produced) and by preserving forest ecosystems and biodiversity. Other trade-offs—particularly in cases where increased energy demand and use is expected—can be reasonably managed by good governance and policy making practices. However, mitigating trade-offs between climate action measures and the SDGs may not always be possible—in some cases there may not be "win-win" scenarios, in which case a decision will need to be taken to identify options that do the least harm.

2.1 SDG and climate action interactions in literature

Linkages between climate action and sustainable development have been recognised by the IPCC since the First Assessment Report (AR1) was released in 1990, however it was not until the Fourth Assessment Report (AR4) that the concept of sustainable development was explored in considerable depth[2]. The IPCC *"…admits the possibility of conflict and trade-offs between measures that advance one aspect of sustainable development while harming another"* (Sathaye et al., 2007, p. 695).

The Fifth Assessment Report (AR5) expands on this, referring to a growing need to understand the co-benefits and adverse side effects of climate change adaptation activities with sustainable development, and deeming it *"…critical to the success of climate policy in the context of sustainable development"* (IPCC, 2014, p. 112). The Report mentions the existence of trade-offs between climate responses and broader sustainable development goals, noting that certain types of climate responses have the potential to: result in additional environmental pressures, redirect resources from development priorities, and/or have distributional effects inherent to the inequalities in modern society (Fleurybaey et al., 2015). It also makes reference to energy production and consumption as being a key intersection point between climate change and sustainable development, particularly with regard to the ability to mitigate emissions (Denton et al., 2015). The Report concludes with high confidence that climate change could potentially counteract poverty reduction (Denton et al., 2015; Fleurybaey et al., 2015)—itself a key factor behind the formulation of the SDGs.

The IPCC's SR1.5 report published in 2018 makes explicit connections between climate action aimed towards limiting warming to 1.5°C and SDGs, specifically mentioning general synergies with SDGs 6 (Clean water and sanitation), 15 (protecting terrestrial ecosystems and halting biodiversity loss), 11 (sustainable cities and communities), 2 (zero hunger), and 3 (good health and well-being) (V Masson-Delmotte et al., 2018). The report takes an optimistic view of potential interactions between climate action and SDGs, noting that "…*the impacts of adaptation on sustainable development, poverty eradication and reducing inequalities in general, and the SDGs specifically, are expected to be largely positive…"* (V Masson-Delmotte et al., 2018, p. 457), particularly due to established links between poverty reduction and vulnerability to climate change.

The interlinked nature of SDGs is explicitly acknowledged in the 2030 Agenda, and as a result a great deal of literature exists on interactions between SDGs including between SDG 13 (climate change) and the others (ICSU & ISSC, 2015; Nilsson et al., 2016, 2018; Pradhan et al., 2017). Most of the research makes a qualitative assessment for characterizing interactions between SDGs and use a framework or 'dimensions' [3] to assess specific synergies between action on climate change and the other SDGs (Nilsson et al., 2016; Epstein and Theuer, 2017; Nerini et al. 2019). Pradhan et al. (2017) propose an alternative data driven method for assessing SDG interactions using correlation analysis of the official SDG indicators at a global level. In

[2] The relationship between sustainable development and climate change is explored in considerable detail in many chapters of AR4: Chapter 2 discusses the growing amount of literature between the two, raising points that are elaborated on in chapters 3-11. AR4 (and successive IPCC reports) demonstrate that the concept of sustainable development has evolved into the mainstream climate change research.

[3] These are: **Geographical context:** e.g. tradeoff between bioenergy and food production is a more significant issue in densely populated regions with insufficient arable land when compared to less densely populated regions like Scandinavia. **Governance:** where the negative nature of an interaction is not inherent to the interaction itself, but attributable more to poor governance. **Technology:** tradeoffs exist, but are likely to be mitigated by technological developments, e.g. zero emissions cars. **Reversibility:** the "permanence" of impacts—will the impacts linger even after a particular intervention/action ceases? **Time sensitivity:** Some interactions play out in real time, others have significant lags. Short term effects can be different from long term effects. **Directionality:** interactions can be uni- or bi-directional.

doing so, they are able to quantify relationships between SDGs, and therefore between climate actions and SDGs via SDG 13.

Most of the research on the interaction between climate action and the SDGs and the interplay across the SDGs is at a macro, high level. However, there is considerable research at the national and local level studying the development benefits and trade-offs from specific various climate change mitigation and adaptation interventions (without necessarily mentioning SDGs). Given the volume of the research available, this review focused on a specific set of typical climate change themes relevant for Asia (Bizikova et al., 2011; Glass et al., 2011; F. Islam et al., 2011). A more detailed review of specific interventions being implemented within these themes for one sample country from each target region is provided in Annex A. The climate action themes selected are: agriculture, water resources management, energy, coastal management, forestry, ecosystems and biodiversity, disaster risk management, and public health.

The table below summarises the findings from a review of available evidence to identify linkages between SDGs and the priority climate action themes for Asia. This is not comprehensive and does not include some of the most obvious synergies. For example, all the climate actions contribute to SDG 13 (climate change) and promotion of renewable energy contributes to the SDG related to affordable and clean energy etc.

Table 1: Interactions between climate actions and SDGs

Climate actions	SDG	Interaction
Renewable energy	SDG 2 – Zero hunger	**Trade-off –** Energy is required for food systems, and the increased energy demand required to ensure zero hunger may be difficult to meet with renewables in the required timeframe (Fuso Nerini et al., 2018).
	SDG 3 – Good health and well being	**Synergy –** Low/zero emission electricity generation has a measurable positive impact on human health (Buonocore et al., 2016).
	SDG 4 – Quality education	**Trade-off** – free and equitable education for all will require an increased supply of electricity to schools. Renewables may not be enough to meet this increased demand given the uptake rate of new renewable generation sources. (Fuso Nerini et al., 2018)
	SDG 6 – Water	**Synergy** – Increasing the share of renewables can reduce water use substantially, e.g. solar and wind expansion will reduce water withdrawals by over 10% in India by 2030. Although some renewable technologies (e.g. biofuels and geothermal can be water intensive). (IRENA, 2015).
	SDG 8 – Decent work and economic growth	**Trade-off** – Energy use (and therefore energy production) is considered necessary for economic growth. (Granger, 1969). Rapidly expanding economies will have rapidly growing energy demands which may struggle to be met by renewables exclusively.
Biofuels	SDG 2 – Zero hunger	**Trade-off –** The use of lands for biofuels can conflict with the use of the same lands for food production in some land-poor developing regions (Mika & Farkas, 2017).
	SDG 6 –	**Trade-off** – increased water demand from bioenergy crops

	Clean water and sanitation	could impinge on availability and quality of water for other uses (Epstein & Theuer, 2017).
	SDG 15 – Life on land	**Trade-off –** Land required for biofuels (and to a lesser extent, renewables) could have significant impacts on terrestrial ecosystems if not managed correctly (ibid).
Climate smart agriculture	SDG 2 – Zero hunger	**Synergy –** Climate smart agriculture and efficient resource use (e.g. improved livestock feeding practices) can generate significant growth in productivity and improve food security (Di Falco et al., 2011; Lipper et al., 2014; V Masson-Delmotte et al., 2018)
	SDG 8 – Economic growth	**Synergy –** Climate smart agricultural practices can be beneficial to farmers and other agricultural stakeholders, while contributing up to 7% of global agricultural mitigation potential through 2030 (Hamidov et al., 2018; Lipper et al., 2014)
Agriculture & forestry	SDG 1 – No poverty	**Synergy** – Agroforestry can mitigate the effects of floods and droughts, contributing to increased livelihood resilience of vulnerable people (Quandt et al., 2017).
	SDG 2 – Zero hunger	**Synergy** – The use of agroforestry systems can increase agricultural yields, particularly for small developing world farmers. It can also increase crop resilience and improve farm livelihoods (Waldron et al., 2017a).
	SDG 8 – Economic growth	**Synergy –** Trees on agricultural land can improve crop production, thereby improving socioeconomic circumstances (Wangpakapattanawong et al., 2017)
	SDG 15 – Life on land	**Synergy –** Agroforestry implemented correctly (as part of a multifunctional landscape) can contribute to biodiversity conservation and enhancement in tropical and temperate regions (Jose, 2012).
Ecosystems and biodiversity	SDG 3 – Good health and well being	**Synergy –** Health of marine systems is directly linked with human health in coastal areas since populations depend on marine food sources (ICSU, 2017).
	SDG 8 – Economic growth	**Trade-off –** Ecosystem protection can result in a loss of other economic land-use types, as local communities might have livelihoods tied closely to natural resources in the ecosystem (V Masson-Delmotte et al., 2018). **Synergy –** Participatory approaches to biodiversity and ecosystem conservation have demonstrated positive impacts on both ecosystems, and community livelihoods (Gurung et al., 2011; Phondani et al., 2016)
	SDG 14 – Life below water	**Synergy** – Oceans and coastal ecosystems are important regulators of the climate. Restoration and protection of these ecosystems improves the resilience of both natural and human systems (ICSU, 2017).
	SDG 16 – Peace, justice and strong institutions	**Trade-off –** Ecosystem protection could result in conflicts over governance of natural resources (ibid).

Forestry	SDG 2 – Zero hunger	**Trade-off** – Increased demand for food can increase pressure on forest ecosystems and result in increased deforestation (Baumgartner, 2019a).
	SDG 6 – Water	**Trade-off –** Reforestation activities such as planting large areas of fast growing trees in degraded forest areas can reduce water availability and increase the risk of drought (Louman et al., 2019). **Synergy –** Reforestation can increase actual evapotranspiration, decrease surface runoff (Trabucco et al., 2008), and control stream salinity (van Dijk et al., 2007).
	SDG 10 – Reduced inequalities	**Trade-off –** Experience from some REDD+ projects has shown inequitable distribution of financial resources at local scales (Louman et al., 2019)
	SDG 15 – Life on land	**Synergy** – SDG 15 includes a target that relates directly to sustainable forest management, afforestation and reforestation, and restoration of degraded forests. **Trade-off** – Planting large areas of fast growing trees in degraded forest areas can reduce resilience and adaptive capacity of those ecosystems (Louman et al., 2019).
DRR	SDG 4 – Quality education	**Synergy –** There is a known link between disasters and school enrolment. Reducing the impacts of disasters on schools can have positive impacts on educational continuity (Epstein & Theuer, 2017).
	SDG 6 – Clean water and sanitation	**Trade-off** – Some DRR measures that impact stream and river flows (e.g construction of dykes and dams to reduce flood and drought risk) can have significant negative effects on water quality and availability (ibid).
	SDG 14 – Life below water	**Trade-off** – As above, flood and drought adaptation measures like construction of dykes and dams can have negative effects on water related ecosystems (ibid).
Resilient health sector	SDG 3 – Good health and well being	**Synergy** – A more resilient health sector will have natural positive implications for public health as a whole.
	SDG 7 – Affordable and clean energy	**Trade-off** – Growth in the energy intensive health services and infrastructure sectors will also increase energy demand significantly which may be difficult to meet with renewables in the required timeframe (Pencheon et al., 2009; V Masson-Delmotte et al., 2018).
	SDG 13 – Climate change	**Trade-off –** The increased energy demand from a growing health system, if not met by renewables, will increase greenhouse emissions (V Masson-Delmotte et al., 2018).

2.2 Regional examples of the interaction between action on climate change and SDGs

Much of the literature explores climate action-SDG interactions at a general level, without referring to specific geographic contexts. The following presents specific research from Asia on the synergies and trade-offs identified in Table 1.

Renewable energy: At present, none of the South Asian countries have a significant proportion of renewable electricity generation (excluding hydro), with India topping out at 5% of total generation, and Bangladesh, Pakistan and Nepal at close to 0% (Shukla et al., 2017). The relatively low penetration of renewable energy in electricity generation in these countries makes the potential trade-offs identified in Table 1 particularly salient. However, there is a strong need for adopting renewable energy technologies in South Asia for climate change mitigation, energy security, and socioeconomic development (ibid). In Southeast Asia—one of the most vulnerable regions to global warming—maintaining sustainable economic and social development while managing emissions through renewable energy has posed an ongoing challenge, and therefore interventions in this space require careful assessment (Z. H. Lee et al., 2013).

Biofuels: The uptake of liquid biofuel production is known to have highly contextually sensitive impacts, varying significantly between developed and developing countries (Pingali et al., 2008). In the South Asian context, there is a clear inverse relationship between biofuel production and child malnutrition, and a positive relationship with per capita calorie availability (Tokgoz et al., 2012), representing significant impacts on SDG 2. However globally, biofuels being net-zero emissions represent a viable option for climate action.

Box 1: CSA—*gher* farming in Bangladesh

Gher farming is a traditional farming method practiced in the low-lying—and therefore flood and cyclone prone—regions of Bangladesh, particularly the coastal districts. *Ghers* are small excavated water bodies surrounded by wide embankments on all sides used for growing rice and following the harvest, for cultivating shrimp and fish (Ali & Meisner, 2017). These embankments protect community livelihoods by offering resilience against floods and cyclones, and providing an elevated platform to grow vegetables and other crops (Sova et al., 2018). In addition to resilience benefits, Rahman and Barmon (2019) found that *gher* farming resulted in significant increases in women's gainful employment and real wage. The potential for increasing resilience, improving livelihoods, and reducing gender inequality has resulted in a resurgence of interest from donors, government, and private finance institutions in recent years (Sova et al., 2018).

Climate smart agriculture (CSA): CSA refers to a broad set of agricultural practices that provide benefits in development, food security, climate adaptation, and mitigation (Lipper et al., 2014). In Central Asia, CSA has significant potential to strengthen agricultural resilience in the face of increased weather variability. A study by Mirzabaev (2018) showed that the adoption of CSA practices had a positive impact on the profits of both rich and poor agricultural households (though the adoption rate of CSA practices was significantly higher in richer households). In Vietnam, Branca et al. (2018) found a strong positive relationship between CSA (sustainable intensification for paddy (SIP), fertilizer deep placement (FDP), and minimum tillage) and farm profitability due to yield increases of 8-10% and 6% respectively.

Agroforestry: Regional Rice Initiative pilot projects in Indonesia, Laos, and Philippines showed that agroforestry in rice production systems contributed significantly to local environmental and socioeconomic conditions by providing food and non-food products, increasing biodiversity, protecting the soil, and improving nutrition (Wangpakapattanawong et al., 2017). Another study looking at the Central Asia region found that unsustainable agricultural practices were key contributing factors to degradation of agricultural land, and that agroforestry is a suitable solution to mitigate these effects (Djanibekov et al., 2016).

Biodiversity & ecosystem conservation: WWF's livestock insurance scheme—piloted in the Ghunsa valley of Nepal—provides a real-world example of synergy between biodiversity conservation and livelihoods. By introducing a community led and managed insurance mechanism to mitigate economic losses to herders from livestock depredation, the programme successfully eliminated retaliatory killings of snow leopards in the area from its first year of implementation (Gurung et al., 2011). In India, a participatory approach promoting the cultivation of medicinal and aromatic plants proved to be useful as a tool for biodiversity conservation and livelihood improvement (Phondani et al., 2016). The success of these approaches suggests that community participation is an important factor in mitigating governance and land-use conflicts when designing implementing conservation interventions.

Box 2: Agroforestry—alley cropping in Tajikistan

Primarily practiced in Tajikistan and Kyrgyzstan, 'alley cropping' refers to the practice of growing crops between wide rows of trees (usually fruit or nut trees). The trees improve productivity by protecting crops from harsh winds and the sun (Djanibekov et al., 2016), while the planting of pulses in between rows of trees enrich the soil (Serikov, 2018). Soil erosion—due to wind and unsustainable intensive wheat cultivation—is also reduced due to the presence of year-round vegetation cover. In parts of Tajikistan, mountain slopes that had been previously facing severe soil degradation leading to significant losses in productivity (Serikov, 2018) have been afforested with rain-fed apple trees, with rain fed wheat in between rows (Djanibekov et al., 2015). This practice has resulted in higher yields, better crop diversity, and increased resilience for local farming communities.

2.3 Mitigating potential trade-offs

Many of the trade-offs identified in this section have potentially severe implications on achieving the SDGs, however there is scope for trade-offs in some areas to be mitigated by synergies in others. For example, the potential trade-off of increased food production putting pressure on forest ecosystems can be reasonably mitigated by adopting agroforestry practices on a large scale or by improving agricultural yields (thus requiring less land area per calorie produced) and by preserving forest ecosystems and biodiversity (Baumgartner, 2019; Jose, 2012; Waldron et al., 2017). Similarly, increased energy use to produce food for growing populations can be offset by the adoption of CSA practices, which can be far more resource efficient than traditional agricultural methods (Lipper et al., 2014).

Other trade-offs—particularly in cases where increased energy demand and use is expected—can be reasonably managed by good governance and policy making practices. As renewable energy uptake tends to be largely policy driven at the national level, the formulation of effective, forward-thinking policies are essential to attract investment in the sector (White et al., 2013).

However, mitigating trade-offs between climate action measures and the SDGs may not always be possible—in some cases there may not be "win-win" scenarios, in which case a decision will need to be taken to identify options that do the least harm.

2.4 Concluding remarks

Given the wide gamut of planned and implemented climate actions from the target countries, it is challenging to comprehensively map out interactions with SDGs as part of a regional exercise. Research shows that climate action interactions with SDGs tend to be highly context-sensitive and so a more fine-grained assessment which may take place on a country, intervention, or SDG level is required.

A majority of the research examined for this section came from secondary review, and theoretical studies. On a regional and national level, there is an absence of primary research that examines specific interactions between climate action and SDGs in the target countries. Such studies could provide important insights into how a particular category of interaction plays out in different countries and regions, and could shed light on the various structural, political, and legislative mechanisms that result in differential impacts between regions.

Much of the literature reviewed around SDG interactions takes a qualitative approach with a wide scope, serving to point towards potential interactions for further investigation. Pradhan et al.'s (2017) approach—which measures interactions by looking for correlations between SDG indicators globally—provides a useful example for quantifying these interactions that can be adapted for programme level contexts.

Viewing climate action/SDG trade-offs as a kind of 'risk', it is immediately evident that an assessment of the *likelihood* of interactions, and their specific impacts is absent from the literature reviewed for this chapter. This is understandable, as likelihood and degree of impact will vary from country to country depending on a number of physical and political factors and reinforces the need to assess interactions at the programme level.

It is also important to note that any single interaction of a climate action with an SDG is almost certainly going to have a cascading effect due to the highly interlinked nature of the SDGs themselves. For example, a climate action that has strong synergy with economic growth could result in higher energy demand which (if not met by renewables) could have trade-offs with other SDGs. This further points to the need to comprehensively assess climate action/SDG, and SDG/SDG interactions at the programme design level, identifying the likelihood, and potential impact of interactions.

3 Economic and social costs of climate change including extreme events

Several studies have attempted to capture the impacts of climate change on economic growth, which show a broad concurrence on the regional distribution of these impacts. By the end of the century, developing countries of the Asia Pacific are estimated to incur 10-15% loss in per capita GDP, from rising temperatures. These are to be examined in conjunction with losses estimated for the region (and occasionally at country level) arising from extreme weather events and climate-induced natural disasters, for a more comprehensive understanding of climate impacts. Estimates show that average annual losses from such events range from 10 to 76% of national social expenditure, representing a huge financial and social burden.

Apart from economic growth, climate change impacts on human well-being are also studied through effects on poverty, inequality, attainment of health, sanitation and education outcomes. Studies have disaggregated these effects into sectors such as agriculture, human health, natural disasters, population risk exposure etc. at a global and regional level to provide indicative estimates over the next few decades. However, the scope of geographic coverage is not uniform (sometimes restricted to catastrophe-stricken zones), and gaps still exist in the availability of quantifiable estimates at a country level.

While comparing across multiple cross-country estimates, methodological differences in models and their assumptions should be noted. Studies vary on the baseline and future emissions scenarios, as well as specification of the growth-climate relationship. Some models are more accommodating of feedbacks of growth on emissions than others which may tend to underestimate economic costs. Hence a review of these estimates should be considered in light of these technical caveats.

3.1 Estimates of economic impacts of climate change, including extreme events

The implications of a changing climate reflected by trends in climate parameters (annual average temperature and precipitation) are the basis to understand consequences on the economy and society. There is a large body of research on various scenarios for addressing climate change – mostly in terms of future economic growth rates, and ambition in limiting global warming (i.e. containing global GHG emissions). The estimates for economic impacts are usually anchored around a *high emissions* scenario (RCP8.5[4] or a temperature increase of 3°C and more) to represent the business-as-usual (BAU) state compared with a *low emissions* scenario (RCP2.6, RCP4.5 or A1B) to represent a world where mitigation efforts are taken into account.

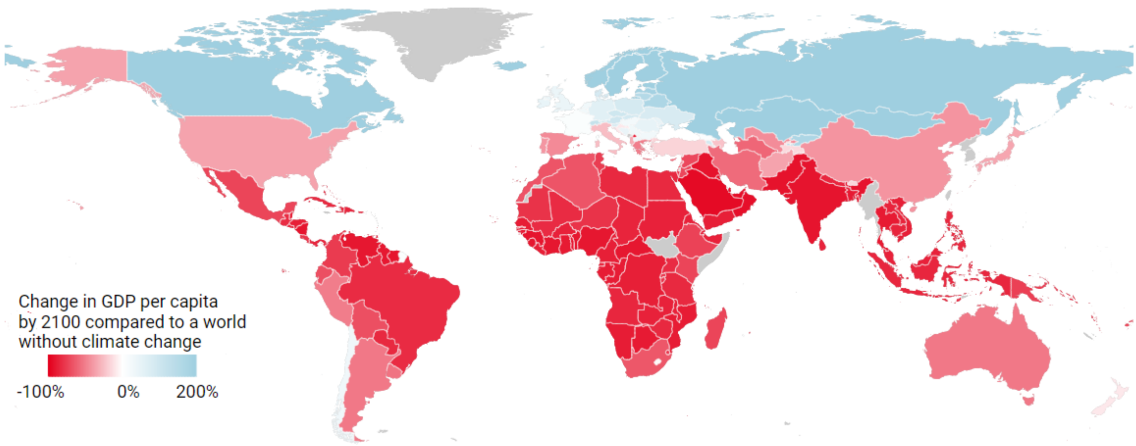
Economic impacts are broadly measured as changes in future GDP growth (per capita, national, regional or at times sectoral). Based on the specific structure of estimation

[4] For detailed definitions please refer to: https://www.ipcc-data.org/guidelines/pages/glossary/glossary_r.html, (Wayne, 2013)

models, these are arrived at through sectoral drivers of growth (leading to sectoral impact estimates), or as direct impacts of climate parameters on projected GDP. Moreover, observed vulnerabilities among communities and global models do indicate that climate change increases already adverse impacts anticipated through population growth, unsustainable use of water, energy and other socio-economic factors (IPCC, 2018).

Among the few analyses that assess climate impacts at the global as well as cross-country levels, it is observed that developing countries in Asia would witness higher costs to growth (Burke, Davis, & Diffenbaugh, 2018; Burke, Hsiang, & Miguel, 2015; Lee, Villaruel, & Gaspar, 2016); IPCC, 2018). While global losses from rising temperature are estimated to be 4.4% of per capita GDP by 2100, for developing countries in Asia it estimated at 11%. Specifically, highest costs are estimated for South and Southeast Asia (15.5% and 13% loss in per capita GDP) by 2100, followed by the Pacific (9.6%). Central Asia would witness a modest increase by 2.5% (Lee et al., 2016). The figure below shows the geographic spread of climate impacts by country, showing a similar trend in the Asia Pacific context. These results indicate a rise in productivity in colder regions, and a loss in poorer tropical countries with already higher baseline temperatures. Outside Asia, the Middle East and North Africa (MENA) and Sub-Saharan African regions account for the largest estimated climate-induced economic losses. Estimates show that developing countries in Africa would lose as much as 27% of their GDP by end of the century, in the absence of any mitigation effort (Kompas et al., 2018).

Figure 1: Country-level estimates of projected impacts of temperature changes on per capita GDP growth by 2100



Source: Burke et al., 2015

A summary of findings from select global and regional analyses is given in the table below, with a brief description of the estimation model, which provides insight into the comparability (or the lack thereof) between various results[5]. Annex B provides country-specific estimates compiled across these sources.

Table 2: Summary of select global and regional estimates of economic impacts of climate change

<table>
<tr><th>Scope</th><th>GDP/Economic Impact</th><th>Remarks on Estimation</th></tr>
<tr><td colspan="3">Global non-linear effects of temperature on economic production (Burke et al., 2015):</td></tr>
<tr><td>Global, with individual country results</td><td>23% reduction in per capita GDP by 2100</td><td>Estimates a non-linear relationship between annual average temperature and growth in real per capita GDP (simple regression framework with partial adaptation) – hence assumes that shocks from climate change will manifest over time
Data from 165 countries, for the period 1960 – 2010</td></tr>
<tr><td colspan="3">Key results[6] (at 95% confidence level):
From a comparison of a no-climate change scenario with RCP8.5 (high growth, rising GHG emissions), SSP5 (shared socio-economic pathway of fossil-fuelled development)
• High impact on per capita GDP growth during 2010-2100: Nepal, Bangladesh and Cambodia (76% to 53% points decline)
• Medium impact: Pakistan, India, Indonesia, Viet Nam, Philippines, Fiji, Samoa, Thailand (36% to 19% points decline)
• Low impact: Uzbekistan, Tajikistan, Bhutan (13% to 5% points decline)
Kyrgyzstan is one of the few countries in this region showing a positive impact on growth (63% points increase).</td></tr>
<tr><td colspan="3">A cross-country analysis of long-term macroeconomic effects of climate change (Kahn et al., 2019):</td></tr>
<tr><td>Global, with individual country results</td><td>7.22% reduction in per capita real GDP by 2100 for a rise in global annual temperature by 0.04°C</td><td>Estimates a stochastic growth model with labour productivity affected by country-specific deviations of temperature and precipitation from historical norms
Data from 174 countries, for the period 1960-2014</td></tr>
<tr><td colspan="3">Key results (at 95% confidence level):
• Impact on real per capita GDP in RCP 2.6 scenario:
• High impact: Bhutan (-10%) and Nepal (-5%)
• Low impact: Tajikistan, Myanmar, Thailand, Viet Nam (less than 1% reduction)
• Impact on real per capita GDP in RCP 8.5 scenario:
• High impact: Bhutan (-18%), Nepal (-13%), Uzbekistan (-12%), Kyrgyzstan (-11%)
• Low impact: Thailand (-4%), Myanmar & Laos (-2%), Cambodia (-0.74%)</td></tr>
<tr><td colspan="3">The Effects of Climate Change on GDP (Kompas et al., 2018):</td></tr>
<tr><td>Global, with individual</td><td></td><td>Estimates an inter-temporal GTAP7 model for long-term impacts of rising temperature on real GDP growth</td></tr>
</table>

[5] The level of confidence reported for each model is also provided, from the respective studies, providing the statistical significance of the estimates (higher the confidence level, greater the strength of the results in representing the modeled impacts).

[6] Only results pertaining to the countries within the scope of this evidence review are highlighted to show the comparative impacts, and not a comparison of all countries analysed in these studies.

<table>
<tr><td>country results and 57 economic sectors</td><td></td><td>Data from 140 countries and regions, and 57 commodities, with 2011 as base year
Climate change impacts are captured through sea level rise, loss in agricultural productivity, impacts of temperature changes on labour productivity and human health</td></tr>
<tr><td colspan="3">Key results (at less than 90% confidence level):
• Impacts of a 3°C rise in global temperature in the long term (by end of century and beyond)
• High impact (between 10 – 15% decline in annual real GDP growth): Philippines, Indonesia, Cambodia, Laos, India
• Medium impact (5 – 10% decline): Thailand, Viet Nam, Bangladesh, Pakistan, Nepal
• Low impact: Kyrgyzstan, rest of former Soviet Union (less than 1% decline)
• Sectoral impacts: Highest impacts on crop produce, agro-based processed outputs (4-6% decline in growth); Lowest impacts on tertiary sector (less than 2% decline in growth)</td></tr>
<tr><td colspan="3">How will climate change affect South Asia’s economic future (Vivid Economics, 2019):</td></tr>
<tr><td>Regional, South Asia</td><td>16% points reduction in GDP growth for every 1°C increase in temperature over a five-year period (effectively halving GDP in 5 years)</td><td>Reduced form estimates of relationship between climate change and economic growth
Data for four countries (Afghanistan, Bangladesh, Nepal, Pakistan) for the period 1990-2005
Use of spatially disaggregated panel data for GDP and climate parameters to account for differences in level of adaptation in different geographies (gridded dataset at 1° resolution)
Structural growth model to relate climate change impacts on individual drivers of economic growth
Growth projections for 2014-2050
Climate impacts captured through labour productivity, agriculture productivity, mortality, migration</td></tr>
<tr><td colspan="3">Key results (at less than 90% confidence level)[8]:
• Longer run impacts estimated for five countries (including India) – projected GDP per capita to be 22% - 33% lower by 2050 than in a scenario without climate change (at RCP2.6 and RCP 8.5 scenarios, respectively)
• Structural modelling results show labour and agriculture productivity losses as the strongest channels affecting growth; geographic and inter-sectoral migration have mixed impacts, based on mobility and availability of adequate employment opportunities elsewhere</td></tr>
<tr><td colspan="3">The Impacts of Temperature and Precipitation Changes on Living Standards (Mani et al., 2018):</td></tr>
<tr><td>Regional, South Asia - with individual country results</td><td></td><td>Estimates non-linear relationship between temperature increases and living standards (as captured by household consumption)
Compares RCP4.5 (climate-sensitive) with RCP8.5 (carbon-intensive) scenarios</td></tr>
</table>

[7] Global Trade Analysis Project – is a computable general equilibrium model including multiple sectors and regions, used to provide macroeconomic impacts in terms of real growth rate
[8] This study reports results which are not statistically significant for *p-values* of 1%, 5% and 10% - hence represent much lower confidence levels in the estimates, as compared to the remaining studies summarised here. However, the authors note that the broad conclusions of direction and magnitude of impact are in line with other comparable assessments of climate-economy linkages.

<table>
<tr><td colspan="3">Key results (at 90% confidence level):
Impact on living standards by 2050, under RCP8.5 scenario
High impact: Sri Lanka (-7%), Bangladesh (-6.7%)
Low impact: Pakistan (-2.9%), India (-2.8%)
Positive impact with rising temperature[9]: Afghanistan (11.9%), Nepal (4.1%)
Impact on per capita GDP by 2050, under RCP8.5 scenario in countries with severe hotspots (where projected consumption spending reduces by more than 8%): Bangladesh (-14.4%), Sri Lanka (-10%), India (-9.8%)</td></tr>
<tr><td colspan="3">Economics of Climate Change in Central and West Asia (ADB, 2016a):</td></tr>
<tr><td>Regional, Central and West Asia – with individual country and sectoral results</td><td>Climate change impacts to cost 1% of GDP per annum up to 2050 in the region, steeply rising to 10% by 2100</td><td>Estimates economic impacts and cost of abatement using an integrated assessment model
Country-specific impacts on agriculture, hydropower and losses from natural disasters
Two scenarios compared: A1B (high emissions) and Paris-compliant (emissions to keep global temperature rise below 2°C)
Includes Afghanistan, Kyrgyzstan and Tajikistan and estimates up to 2100</td></tr>
<tr><td colspan="3">Key results (at 90% confidence level):
Net present value (NPV) of mitigation cost is USD 2,586 bn, nearly five times the NPV of adaptation costs, at USD 531 bn
Large mitigation costs are attributable to the aggressive target assumed in the Paris-compliant scenario</td></tr>
<tr><td colspan="3">The Economics of Climate Change in the Pacific (ADB, 2013):</td></tr>
<tr><td>Regional, Pacific
(includes sectoral impacts)</td><td></td><td>Two models (PAGE09 and FUND3.6) estimated for multiple climate scenarios
A1B (high growth, medium emissions, balanced use of fossil fuels) and A1FI (current fossil-fuel intensive growth profile, closest to business-as-usual) scenarios key to expressing the range of results from the models</td></tr>
<tr><td colspan="3">Key results (at 90% confidence level):
Cost of climate change to annual GDP equivalent
Highest impact: Papua New Guinea (15.2%), Timor-Leste (10%)
Medium impact: Vanuatu (6.2%), Solomon Islands (4.7%)
Low impact: Fiji (4%), Samoa (3.8%)
Sectoral costs on regional annual GDP equivalent by 2100: 5.4% from agricultural yield reduction; 2.8% from additional cooling requirements; 1.3% from coastal areas (land loss, forced mitigation); 0.8% from morbidity and mortality</td></tr>
</table>

Source: Review by study team

Some observations from the review include:

High rates of economic impacts: While the estimated impacts at the regional level across studies are consistently high for developing countries in Asia Pacific, some countries feature with relatively higher economic costs include Nepal, Bhutan, India,

[9] This is consistent with findings from similar studies that increase in average temperature is associated with rise in productivity in colder countries, as does projected increase in precipitation in countries with limited water resources.

Bangladesh, Philippines, Indonesia, Cambodia, Thailand and Pakistan. However, this is more of an indicative list for the sample, and as the table above shows, specific estimation techniques and assumptions can cause some differences in the results.

An underestimation of impacts: There is an acknowledged limitation in capturing losses from extreme events, which renders most of these estimates as potential underestimates of costs - or overestimates, wherever positive impacts of temperature rises are shown (Ahmed & Suphachalasai, 2014; Kompas et al., 2018; Vivid Economics, 2019). In this regard, estimates from cross-country (as compared to country-specific) models, are more prone to this limitation because deviations from normal growth rates get averaged out both over time and space. Hence these results should be considered along with literature on the cost of natural disasters and extreme events. One of the ways to do this is to estimate effects of climate shocks directly on the factors of economic growth, allowing for non-linear effects (Bakkensen & Barrage, 2018).

One of the other relevant measures is therefore the long-term average cost from catastrophes – defined as the average annual losses (AALs). The AALs from disasters in the Asia Pacific region have been increasing rapidly, and range widely from 10-76% of the share of social expenditure of countries (UN ESCAP, 2016). Bangladesh and Philippines have relatively higher AALs – at 48% and 69% respectively, while countries on the lower side include India (9%), Indonesia (7%) and Thailand (5%). Among the sources of these losses, extreme events with climate linkages such as droughts, tropical cyclones and floods account for over 85% (UN-ESCAP, 2019).

Differences in time horizons: Studies also observe a higher adverse impact faced in the latter half of the century (2050-2100) than up to 2050. For instance, in the Pacific, climate change would cost up to 3.5% of regional annual GDP equivalent by 2050, rising to 13% by 2100 (ADB, 2013). Estimates for South Asia show that up to 2050, the loss in GDP in a BAU scenario would average 1.5%-2% annually; but 7-10% in the longer term, if climate responses were absent (Ahmed & Suphachalasai, 2014).

Similarly, for a 3 degree rise in temperature (an estimate for global warming relatively unhindered), GDP for Cambodia, Indonesia and Philippines would reduce from about 1.2% per annum by 2027 to between 12-14% per annum in the long run (beyond 2070). For India and Pakistan, the loss in per capita GDP ranges from 3-4% by 2050, to 9-10% by 2100 (Kahn et al., 2019). However, this gradient over time is far less steep in Kyrgyzstan, for instance, starting with a modest annual *increase* in GDP of less than 0.01% and worsening to less than 1% annual GDP reduction (Kompas et al., 2018).

Economic gains from climate-sensitive growth: Some studies also show the different impacts of a BAU as compared to a Paris-compliant scenario (limiting global temperature rise to below 2°C). This points to gains from adopting a climate-sensitive growth and emissions pathway, especially for poor, developing countries (Burke et al., 2018). For instance, countries that gain most from following RCP2.6, as compared to RCP8.5 include Kyrgyzstan, Tajikistan, Pakistan, Uzbekistan, Nepal, Bhutan, India – by reducing loss to economic growth by more than 7% points (Kahn et al., 2019).

Sectoral economic impacts: Apart from GDP growth impacts, some studies also provide a sectoral profile of climate impacts (ADB, 2016b, 2016a; Centre & Development, 2018; Reyer et al., 2017; *Southeast and East Asia Regional Climate Risk Synthesis Report*, n.d.). These also inform relative threats and opportunities over time, across sectors (e.g. the initial years of projected climate change in some central

Asian countries does not immediately impact crop output, given the lower reliance on rain-fed farming, however heat stress on the other hand is a more prominent risk in due course). At a global level, farm output and agro-processed outputs are estimated to decline the most (4-6%) (Kompas et al., 2018).

In line with the IPCC's profiling of risk, South and Central Asia shows greater vulnerability from river and coastal flooding (in terms of population exposed), and farm area exposed to a reduction in crop duration and heat stress (Centre & Development, 2018). In addition to these sectors, high human health impacts from heat stress is also noted in South East Asia (Shrestha et al., 2019).

3.2 Issues in estimating economic impacts of climate change

Climate impacts are estimated by modelling economic growth with assumptions on climate scenarios to infer relative costs of responding to and/or ignoring climate change effects. These effects are usually a rise in temperature, changes in rainfall variability, sea level rise etc. Most commonly used approaches include integrated assessment models (and their subset - computable general equilibrium (CGE) models[10]), apart from purely econometric estimation. Their application provides results to infer potential changes in growth rate, cost of adaptation/mitigation, which usually can inform policy makers on the scale of the climate risks they face.

Some variations of these models allow for estimating multiple time points in the future (rather than just two time points of now and future). To derive sectoral impacts from economic modelling, damage functions (which relate climate change as a cause to the resulting damage on an observed indicator) also get introduced (ADB, 2016a; Economist Intelligence Unit, 2015; Kompas et al., 2018; Vivid Economics, 2017). Statistical analysis is also used to understand economic impacts from past climate trends, however this is limiting as the relationship between the climate and economy in the future is assumed to remain the same. There is scope for variations in results in sector-specific studies as well, based on data availability, specific indicators used, geographic coverage etc. (Blanc & Reilly, 2017).

Some of the caveats that emerge from the studies are listed below, in decreasing order of significance in clarifying modelling results:

- The models do not adequately allow for randomness within the analytical framework – needed to represent the occurrence of extreme events (as earlier mentioned) (Kompas et al., 2018; Valérie Masson-Delmotte et al., 2018). In this study region, the need to account for the effects of extreme weather events, changes in availability of water resources etc. is important, given that coastal areas would be exposed to sea level rise and increasing frequency and intensity of storms (Mani et al., 2018).
- The inability (in some models) to include effects of shocks to biodiversity, air quality, ecosystem changes from invasive species spread, migration etc. These are also effects of climate change that need to be included while projecting economic

[10] Integrated assessment models are of two kinds: fully integrated and non-CGE: while the former allows for interactions between the economic and climate systems, the latter takes the economic system as exogenous (hence underestimate climate impacts) (ADB, 2013)

impacts (Kompas et al., 2018; Mani et al., 2018; Valérie Masson-Delmotte et al., 2018).

- While comparing estimates, the underlying climate change scenario assumption must be first identified – some models assume rather stringent emission reduction efforts, thereby changing the temporal distribution of economic costs, as compared to others (ADB, 2016a). This could result in higher costs than other scenarios.

- Some models do not accommodate feedback effects of growth on emissions (by taking climate parameters as completely exogenous), also causing underestimation of economic costs, and overestimating temperature thresholds described above (Auffhammer, 2019; Kahn et al., 2019).

- A related aspect is the nature of relationship estimated between climate parameters and growth – studies that have specified a non-linear association express different results (Burke et al., 2015; M. Lee et al., 2016). These results show that there is a threshold of temperature up to which it has a favourable impact on growth, beyond which negative returns emerge. Hence while comparing with other models, this must be kept in mind – that non-linearity gives an aggregate impact over time which appears as a larger quantum of impact (e.g. from 2010 up to 2050 or 2100) rather than an annual average cost (which would be a linear, i.e. uniform rate of reduction per year like found in (Vivid Economics, 2019)).

- Most models (as a result of some of the points listed already) take into account short-term effects – that is, how growth responds in the short-term, to shocks in climate change parameters. Therefore, by assuming that the economy will behave in the same manner as observed over the past decades (static approach), this tends to ignore the longer term adjustment of the economy and businesses in adapting to emerging new normals in temperature/precipitation (more dynamic, by exploring multiple channels of how climate interacts with growth indicators) (Kahn et al., 2019; Vivid Economics, 2019).

- Similarly, extreme events and other shocks would cause governments to become significantly indebted, and hence be constrained to support economic growth in the BAU manner. This additional fiscal burden also needs to be factored in (Kompas et al., 2018).

- Models assume that country commitments on emissions reduction will be met, but this can be unrealistic, especially in longer term models (Kompas et al., 2018; Vivid Economics, 2019).

For these various reasons, it is important to consider results from such analyses as indicative of the direction and relative extent of climate impacts, rather than as accurately predictive.

3.3 Alternative measures of socio-economic impacts of climate change

Other dimensions that have been analysed for climate impacts include social parameters such as inequality, health, education etc. This is not always visible in analyses focusing on growth dynamics, and regional/extreme event-based reports tend to have more information on impacts across social groups.

In the Asia Pacific region, there is a high proportion of population residing in `high-multi-hazard-risk areas': ranging from Pakistan, Nepal and Afghanistan (30-40% of population) to Philippines, Viet Nam and Bangladesh (above 75% of population) (UN-ESCAP, 2019). This leads to negative spill overs in economic and social well-being: particularly on outcomes related to sanitation, health, continuity in education, women and girls (ibid). For instance, a 1 percentage point increase in climate risk exposure causes a widening of the Gini coefficient by 0.24, increase under-five mortality rate (U5MR) by 0.3 and lower education rates by 0.26 percentage points (UN-ESCAP, 2019). Similarly, indicators such as forest carbon pool, net biome productivity (forests); share of dryland and wetland area impacted (sea level rise), gap in power demand met (energy), morbidity and mortality from communicable diseases (health) are also reported against (ADB, 2016b).

An assessment of Central Asian countries that shows that national development that disregards regional climate risks leads to social tensions (in river water sharing) and reduced regional cooperation (Omelicheva, 2018). Similarly, civil conflicts and crimes have been studied as functions of rising temperatures, with positive linkages estimated (Carleton & Hsiang, 2016).

Various channels through which climate change impacts social, and specifically gender, inequalities, have also been reviewed. One of the key indicators of climate risk exposure of floods is the high share of disadvantaged groups living in delta, flood-prone, low-lying areas, in both rural and urban contexts (N. Islam & Winkel, 2017) (Rao et al., 2019). Similarly, sectoral disaggregation of climate impact channels on poverty shows that agriculture would be the key source of adverse impacts on the poor (Hallegatte et al., 2016). The impact of climate change on food production and food prices are estimated to increase the population living below extreme poverty by 67 million in a high impact scenario, as compared to 6.3 million in a low impact scenario by 2030. Health impacts are estimated to tip 4 to 28 million more people into extreme poverty; while impact of natural disasters on poverty comes next, increasing the poor population by 1.5 to 5.6 million people between the two scenarios (ibid).

In respect of natural disasters, impacts are also captured in terms of fatalities, number of people affected etc. A greater focus on local level economic impacts is possible, which are more insightful, than a national aggregation (diluting the impact at the local level). This leads to the use of alternate measures/proxies to economic activity (data on is challenging at the local level) – an example being the use of nightlight intensity to study post-storm impacts on local economy in Philippines (Asian Development Bank, 2018). Other impact dimensions that are documented include indebtedness, conflicts that arise from weather-related shocks (to resource access), mismatched market prices (e.g. real estate values not reflecting true risk from climate, despite evidence), SME activity, etc. (ibid).

There remain gaps in more specific/layered research on differential impacts across social groups on demographic factors (morbidity, geographic migration, labour mobility), human capital, despite the identification of stronger impact channels (i.e. through capital and labour productivity) (Vivid Economics, 2019). One of the key areas that need to be strengthened is the provision of projections across scenarios, that vary not only on emission pathways, but also on degree of adaptation that the society is expected to achieve in the future. This becomes also important to identify instances where a future scenario with adaptation can be possible for specific climate risks, at lower costs than anticipated (Carleton & Hsiang, 2016). This becomes relevant not only for mainstream growth projections, but also in the process of unpacking social channels of climate impacts.

3.4 Concluding remarks

Studies on a global scale have greater coverage of country-specific economic impacts, as enumerated in this section, and continue to serve as starting points for this empirical discussion. However, beyond a regional concurrence in the estimated impacts on GDP growth or productivity from rising temperatures, there is also an observed diversity in what these numbers represent, owing to the different modelling assumptions. This continues to attract debate, as there is no unique ideal approach to this exercise. However, future efforts can be pointed towards developing greater sectoral insights, on a more regional/national scale, to inform decision-makers with action-oriented results (Auffhammer, 2019). Currently, information at a local level is more readily available in the context of extreme events, which capture more layers of social impacts.

For South and Southeast Asia, observed and projected climate impacts on human settlements, coastal systems and select health indicators are relatively better documented, than other important sectors like agriculture, water resources, biodiversity etc. (Auffhammer, 2019). Evidence gaps also exist in in more specific/layered research on differential impacts across social groups on demographic factors (morbidity, geographic migration, labour mobility), human capital, despite the identification of stronger impact channels (i.e. through capital and labour productivity) (Vivid Economics, 2019).

From the above discussion, it is evident that addressing issues around modelling approaches would be key to increasing the value of efforts in this domain (DeFries et al., 2019) (Barron, 2018), which include:

i) accounting for social benefits (or costs) from changes to growth determinants,

ii) including shifts in technology and sectoral transformation (e.g. transport, energy efficiency) in whose absence, underestimation bias persists

iii) accounting for disruptive changes caused by climate shocks/deviations in climate parameters that cannot be limited to what models currently only may capture as a persistence of adversity (or a *fading out effect*)

iv) moving towards adoption of best practices in climate-economy modelling that entails transparency in data, model assumptions, specification and limitations

4 Climate change vulnerability ranking of countries in Asia

This section explores concepts of vulnerability in global literature, and in particular four climate vulnerability rankings: Germanwatch's Global Climate Risk Index (CRI), the University of Notre Dame's Global Adaptation Index (GAIN), UNEP and SOPA's Environmental Vulnerability Index (EVI), and DARA's Climate Vulnerability Monitor (CVM).

There are different conceptual understandings of the term 'vulnerability' which guide the methodological principles behind each of the indices explored. Each index therefore has a unique set of underlying assumptions that significantly affects the overall results. There is a fairly high degree of variability in the target countries' performance in each of the indices, and in some cases countries like Bhutan appear to be highly vulnerable in one index, while not significantly vulnerable in another.

The variability in results and differences in methodological principles for each ranking suggests that there may not be a perfect index or ranking methodology. Coupled with the somewhat flexible nature of the term 'vulnerability', it is difficult to determine precisely the degree to which an index captures a country's true vulnerability to climate change. It is therefore important—particularly in decision making contexts—to first understand what type of information is required (influenced by the specific nature of the decision being made, and the intended consequences of an intervention), and to choose an appropriate index based on this, or develop a bespoke index if an appropriate one does not already exist.

Out of the indices explored in this chapter, the University of Notre Dame's GAIN is perhaps the most reliable metrics for setting a baseline and measuring progress for a regional resilience programme, primarily due to its methodological rigor, and regularity of data. The open source nature of the index also lends itself well to being adapted for different contexts.

4.1 Introduction

Within climate change literature there is a considerable amount of variation in the definition of the term 'vulnerability' and the understanding of the concept has evolved over time. For example, in AR4, the IPCC defines 'vulnerability' as *"the degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change…"*(IPCC, 2007, p. 89). Under this definition, vulnerability is a function of "…*type, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity."* (Ibid, p. 89).

Following developments in global literature on the term, the IPCC modified its definition in AR5 to be *"…a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt"* (IPCC, 2014, p. 128). Notably, the AR5 definition separates exposure from the overall concept of vulnerability, and redefines it to refer to the "…*presence of people, livelihoods, species, or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected*" (Ibid, p. 123).

Expectedly, the vulnerability rankings and indices explored in this section differ significantly not only in their conceptual definitions of vulnerability, but also in how those concepts are applied in terms of calculation methodology and interpretation of the results. The evolution and lack of consensus of the definition of vulnerability points to a key limitation of climate vulnerability rankings and indices, and suggests that there is no objective way to measure it. It is therefore crucial to understand the methodology and limitations of any ranking or index before using it for decision making.

This section explores four climate vulnerability rankings and indices, noting the scores/classifications of the target countries, and comparing methodologies to gain insights into applicability for the target regions[11]. The rankings reviewed for this section were:

1) The Global Climate Risk Index (CRI) published annually by Germanwatch
2) The University of Notre Dame's Global Adaptation Index (GAIN)
3) The Environmental Vulnerability Index (EVI) developed jointly by the South Pacific Applied Geoscience Commission (SOPAC) and the United Nations Environment Programme (UNEP)
4) The Climate Vulnerability Monitor (CVM) developed by DARA and the Climate Vulnerable Forum.

4.2 Global Climate Risk Index (CRI)

The CRI is unique among the rankings presented in this section because rather than aggregating indicators for the various dimensions of vulnerability in the IPCC definition (exposure, sensitivity, and adaptive capacity), it is entirely based on quantified impacts of past extreme weather events[12]. In doing so, it captures the 'exposure' component of vulnerability empirically rather than hypothetically (Eckstein et al., 2019).

The CRI aggregates four indicators collected from 1998-2017: number of deaths from extreme weather events; number of deaths per 100,000 inhabitants; sum of losses in US$ PPP; and losses per unit of GDP. The index score for each of the index's 181 countries is derived by taking a weighted sum of the indicators. This approach means that the CRI is essentially scoring and ranking the countries most affected by climate change related weather events over the past twenty years.

A few additional implications of this approach are:

1) Population growth can potentially reduce the apparent vulnerability of a country due to the presence of the deaths per 100,000 indicator.
2) Economic growth can also reduce a country's apparent vulnerability due to the loss per unit of GDP indicator.

These implications represent significant limitations of the CRI approach. First, the 'number of deaths per 100,000' indicator can be viewed as a rough analogue for

[11] Indices were selected based on transparency of the underlying methodology (some indices required payment to access data, and had closed, proprietary methodologies), global applicability (others applied to specific types of ecosystems), and frequency of use in literature.
[12] These include meteorological, hydrological, and climatological events.

exposure (under the IPCC AR5 definition), so an increase in population (assumed to be uniformly distributed in a particular country) should translate to increased vulnerability. However, in the CRI, an increase in population in a given year without a corresponding increase in number of deaths translates into a *decrease* in vulnerability score.

Second, while economic growth has been linked with improved ability to cope with climate change (thus reducing vulnerability), this process is not guaranteed, and requires the "*right*" kind of growth (Bowen et al., 2012). For example, growth in water intensive agricultural sectors in water scarce regions would intuitively increase the severity of climate change impacts, while shifting from agriculture towards manufacturing would likely have the opposite effect (Ibid).

4.3 Global Adaptation Index (GAIN)

GAIN appears to use the AR4 definition of vulnerability, viewing it as a combination of exposure, sensitivity, and adaptive capacity. Additionally, it measures a country's readiness to leverage private and public sector investments for adaptive actions (Chen et al., 2015). The index is therefore made up of two sub-indices: vulnerability and readiness to adapt. This section looks only at the vulnerability component.

Unlike other vulnerability measurements explored in this study, GAIN links vulnerability with specific sectors that it considers to be "life supporting" (Chen et al., 2015). These are: food, water, health, ecosystem services, human habitat, and infrastructure. Six indicators are selected for each sector to represent exposure, sensitivity, and adaptive capacity. A total of 36 indicators are used to develop the vulnerability index. In contrast to the CRI, GAIN does not include empirical data on the impacts of past climate-related disasters, so a country's vulnerability as determined by GAIN can be viewed as hypothetical. Like the CRI, the index ranks 181 countries with available data.

Also notable is the absence of GDP as an indicator in the calculation of GAIN's vulnerability index. According to the authors, this was done to avoid doubly penalizing developing countries, as the index already shows high correlation with a country's economic status (Chen et al., 2015).

A key limitation of the GAIN approach to assessing climate vulnerability is its use of the AR4 definition of vulnerability which does not emphasize the concepts of risk and resilience (Jacobs & Al-Azar, 2019; Leiter, 2017).

4.4 Environmental Vulnerability Index (EVI)

The EVI was developed to provide a standardized framework for assessing vulnerability. Vulnerability in this context is defined as a function of three components: risks associated with hazards; resistance to hazards; and acquired vulnerability. The first component is probabilistic in nature and refers to the likelihood of hazard impacts. The second refers to the inherent characteristics of a country that make it more or less able to cope with hazard events. The third refers to the vulnerability that has been acquired through damages such as loss or degradation of ecosystems, using the assumption that more degraded ecosystems are more vulnerable to future hazards (Kaly et al., 2004; UNEP & SOPAC, 2005).

The index is based on 50 indicators observed over the previous 5 years that are combined by simple arithmetic averaging. Of these 50 indicators, 32 pertain to the first component (hazards), 8 to the second (resistance) and 10 to the third (acquired vulnerability). Each indicator is scaled (on a relative basis) from 1-7. Coverage for these indicators is fairly comprehensive, and the index includes 239 countries, and all of the target countries for this study.

It is worth noting that the EVI is intended to be used as a framework for vulnerability assessments, with the framework being the main output of the exercise. The index's webpage provides comprehensive guidance on how to apply EVI principles to any given country. Therefore, it is not regularly published or updated (as in the case of GAIN and CRI), and the most recently updated set of results is from 2004.

4.5 Climate Vulnerability Monitor (CVM)

The CVM was developed as a conceptual framework to determine national level vulnerability to climate change. The definition of vulnerability used here aligns closely with the AR5 definition of "risk", of which vulnerability (sensitivity and adaptive capacity) and exposure are components.

The index uses 34 indicators for 184 countries that measure economic, human, and ecological effects of climate change to assess impacts on human health, weather, human habitat and economics. For each indicator, impacts between 2010 and 2030 are calculated based on varying emissions scenarios. Each country is scored from 1-8 on each of the four impact areas (1 = low, 8 = acute) and the overall score is determined by taking a weighted average (DARA, 2012). Due to this scoring system, many countries have the same overall score, so it is not possible to create a country-wise ranking (Stanton et al., 2012).

4.6 Comparison of rankings for target countries in Asia

The table below shows the results for the 14 target countries for each of the vulnerability rankings and indices explored in this section. Notably, there appears to be a substantial amount of variability between how a target country scores from one index to the next.

Table 3: Comparison of target countries in four vulnerability rankings/indices

Country	Average	CRI	GAIN	EVI[13]	CVM[14]
	Average of CRI, GAIN, ad EVI	*For CRI, GAIN, and EVI, a country ranking is provided. Higher ranking (lower number) represents higher vulnerability. CRI ranks 181 countries, GAIN ranks 239 countries, and CVM ranks 184 countries*			*Higher scores represent higher vulnerability (1-5)*
India	**28**	14	51	19	5
Philippines	**33**	20	71	7	4
Pakistan	**37**	33	50	27	5

[13] EVI does not have a published ranking (the report relies on a 5 point classification system from most to least vulnerable) so this ranking was created by the author using raw EVI score data.
[14] 1-low, 2-moderate, 3-high, 4-severe, 5-acute

Vietnam	**38**	6	63	44	5
Bangladesh	**38**	9	36	68	4
Nepal	**55**	4	47	115	3
Indonesia	**74**	50	78	94	4
Myanmar	**93**	69	38	172	5
Laos	**98**	48	42	203	5
Cambodia	**110**	115	46	170	5
Bhutan	**122**	124	53	189	3
Tajikistan	**124**	107	82	182	4
Kyrgyzstan	**125**	52	114	208	4
Uzbekistan	**133**	124	121	155	3

Source: Compiled by the authors from different sources including Chen et al., 2015; DARA, 2012; Eckstein et al., 2019; UNEP & SOPAC, 2005.

In particular, Bhutan has considerable variation in its vulnerability rank: on the CRI and EVI, it places relatively low in the order, suggesting low vulnerability—however its GAIN ranking puts it in the same neighbourhood as India, Nepal, Pakistan, and Bangladesh, three of which are among the top 15 most vulnerable countries in the CRI. Meanwhile, its CVM score of 3 indicates 'high' vulnerability, but not at the same level as countries like India and Pakistan which both have scores of 5.

This discrepancy can be attributed largely to the underlying methodologies for each of the rankings. In this case, Bhutan's apparent low vulnerability on the CRI indicates that during the CRI aggregation period (1998-2017), it incurred considerably fewer economic and human losses than other South Asian countries. Conversely, its relatively high vulnerability classification on the GAIN index suggests that the theoretical possibility and potential impact of climatic events is high, even if the country has not felt significant impacts at present.

Cambodia is similarly ranked in the CRI as falling outside of the top 100, while GAIN suggests that it is more vulnerable than any South Asian country except Bangladesh. It also receives the highest (most vulnerable) classification on the CVM.

On the EVI, only Philippines appears in the top 10. Only 3 target countries (including Philippines) are in the top 50, and only 5 are in the top 100. This could partially be because the EVI includes 239 countries which is the most out of any index we have looked at. It can also potentially be explained by the dated nature of the most recent EVI results (2004).

4.7 Variation between indices

The table below shows the variation in ranks for each country on the CRI, GAIN, and EVI, ordered from least to most variance. The variation value[15] illustrates the difference in position for each country across the three indices (i.e. the degree to which a particular country's ranking is similar or dissimilar across all three indices). For example, a variation score of 0 would indicate that the country is ranked the same on each of the three indices. Therefore, low variation scores (such as for Pakistan and India) suggest that there is greater consensus between the indices on the degree of vulnerability than for countries with high variation scores such as Laos and Kyrgyzstan.

Table 4: Comparison of variation in country rankings on CRI, GAIN and EVI

Country	Variation
Pakistan	12
Uzbekistan	19
India	20
Indonesia	22
Vietnam	29
Bangladesh	30
Philippines	34
Tajikistan	52
Nepal	56
Cambodia	62
Myanmar	70
Bhutan	68
Kyrgyzstan	79
Laos	91

Pakistan has the lowest variation score of 12 due to the relatively small difference in ranking across the CRI, GAIN, and EVI (33, 50 and 27 respectively). On the other hand, Laos has the highest variation score—it is in the top 50 most vulnerable countries on the CRI and GAIN, but is outside the top 200 on the CVM.

The disparity in results between rankings highlights the wide variation in the ways of measuring and ranking vulnerability. It is clear that no index or ranking is perfect, and it is not possible to determine the relative vulnerability of countries using a single metric. The results of each index are a product of the choice of indicators, and the underlying

[15] The value is a statistical measure for variance calculated as the square of the standard deviation of the dataset comprising the country's rank on the CRI, GAIN, and EVI (3 data points in total).

methodological framework and assumptions. Additionally, varying interpretations of the concept of vulnerability make it different to compare between indicators to confidently determine the degree to which an index captures a country's actual vulnerability to climate change.

The table below lists some of the relative strengths and weaknesses of the indices explored in this section.

Table 5: Strengths and weaknesses of vulnerability indices

Index	Strengths	Weaknesses
CRI	- Published annually since 2007 - Based on empirical rather than theoretical indicators, so gives a better picture of vulnerability based on actual economic damage and loss of life - Economic loss indicators expressed as % of GDP, which provides a truer assessment of impact	- Does not include aspects such as rising sea levels and ocean warming - If a country does not experience extreme weather events in a particular year, its vulnerability could be underreported—a limitation of the empirical approach - Does not include indirect effects, e.g. food scarcity resulting from heatwaves - Only includes deaths as its metric for human impacts, and does not measure number of people affected - Does not include gender indicators
GAIN	- 36 component indicators capture a wide range of vulnerability factors organized by sector (food, water, health, etc). This makes it possible to assess the sector-wise vulnerability of a country - Methodology is transparent, and is documented in a detailed technical paper.	- Methodology has changed between editions, so results from current version are not directly comparable with those from previous versions - Some predictive indicators rely on single models, and it is not clear why those models were chosen over others, e.g. projected change in groundwater recharge, and deaths from climate change induced disease - Does not include gender indicators
EVI	- Well documented and allows for reproduction of results and adaptation of methodology - Identifies specific areas of environmental concern - Greater geographic coverage—includes 230+ countries compared to around 180 for other indices. - Expansive list of empirical indicators	- Out of date—the last published update of results was in 2004 - More of a framework that is intended to be adapted for specific purposes/countries, rather than a published country-wise ranking - Subjectivity in selection and weightage of indicators - Does not include gender indicators
CVM	- Separates human impacts from economic impacts	- Lack of transparency—there is no detailed documentation of the methodology

	- Scoring is not granular enough to rank countries—index score falls between 1and 5. - Last update was published in 2012 - Does not include gender indicators

4.8 Concluding remarks

In terms of methodological robustness, GAIN and EVI capture significantly more dimensions of climate vulnerability than the CRI or CVM. The CRI for example only measures four indicators related to loss of life or GDP. The methodologies behind GAIN and EVI are also strongly grounded in scientific research, with GAIN having been developed at the University of Notre Dame, and EVI by a consortium of universities and intergovernmental organizations. Finally, both GAIN and EVI are fully transparent, and provide detailed methodological notes and technical guidance documents.

On the other hand, the CRI and CVM seem to be produced less for research practitioners, and more for general audiences. Their primary outputs are well designed, eye-catching publications that do not include detailed sections on methodology. The impact of this approach appears to be evident: a web search for news articles mentioning the annually updated CRI returned over 4000 results, while GAIN returned under 200.

Given that none of the indices explored in this section have any significant unaddressed[16] methodological shortcomings, it is useful to get a sense of the average ranking for countries across indices, shown in the first column in The table below shows the results for the 14 target countries for each of the vulnerability rankings and indices explored in this section. Notably, there appears to be a substantial amount of variability between how a target country scores from one index to the next.

Table 3. When the list of target countries is sorted by this average ranking, we see that the three Central Asian countries (Tajikistan, Uzbekistan, and Kyrgyzstan) are grouped together as the least vulnerable. This can be partially explained by the fact that none of these countries have coastlines, which is an indicator in both GAIN and EVI; and the region has a relatively low population which is an important factor of vulnerability. However, a more detailed statistical analysis is required to precisely identify the cause behind this grouping.

It is clear that climate vulnerability indices have relative strengths and weakness. Before relying on any single index or ranking, it is therefore important in a decision-making context to:

- Have clarity on *how* the index or ranking will be used for decision making. will rankings inform funding decisions and programme prioritisation? Will programme design themes be dependent on the various dimensions of vulnerability measured by the index? For identifying thematic areas for a programme—indicator level information from vulnerability indices like GAIN or EVI is useful for highlighting priority intervention areas. However, for decisions

[16] Publications for all of the indices included sections explaining limitations, and providing precautionary guidance on application of the indices.

related to levels of programme funding, indices should be used as part of a wider decision-making framework.

- Understand what information is required about the countries being assessed in order to capture a contextually appropriate measurement of vulnerability. This should be informed largely by the nature of the decision being made and the intended consequences of interventions being considered. For example, a programme aimed at improving agricultural resilience in Central Asia would not be well-served by an index that includes a lot of indicators dealing with coastal ecosystems. In this case an indicator like GAIN which has more general, region agnostic indicators would be preferable. Alternatively, sector specific indices such as the Water Exploitation Index and the Nomura Food Vulnerability Index can be used at the programme level.

The idea of applying global indices for regional or sub-regional decision-making processes is also something to approach with caution. Leiter (2017) warns of a significant trade-off between global comparability and local context. Global indices use globally available indicators at the national level, and are unable to incorporate sub-national indicators (which may give a may give more granular results and allow for intra-country comparability), or integrate local knowledge systems as emphasised by Article 7.5 of the Paris Agreement.

Given that the sourcing and aggregation of data in vulnerability indices tends to be relatively straightforward, it may be better to adapt one of these methodologies and develop a custom regional or sub-regional index to more appropriately capture the specific information that is required.

5 Relevant metrics for climate change resilience and biodiversity

Metrics are used to measures progress in building socio-economic resilience to climate change and for conserving biodiversity. However, there are significant conceptual, methodological and practical challenges to developing and using such metrics. There are large number of measurement frameworks documented in global literature which deal with both social and ecological dimensions of resilience. However, while there are some overlaps in indicators for resilience, there is a great deal of variability too which is informed by management objectives as well as social and geo-physical characteristics. There are, hence, no standard frameworks or indicators for socio-economic or ecological resilience that are applicable under different contexts and management objectives.

The underlying challenge for measuring climate change resilience in particular is a lack of consensus on what the concept means for a given objective and context. It remains a highly contested field of knowledge. As a result, each measurement framework has been developed using a different understanding and set of dimensions for resilience. While the concept of vulnerability is also contested (see section 4) it has received more research attention and therefore has a more developed set of measurement frameworks. As such, it may be more appropriate to focus on measuring vulnerability to assess progress in the first instance, i.e., change in ability to meet basic needs, access to external resources, and ownership or control of (physical, economic, human, social, economic) assets.

5.1 Climate change resilience metrics

Climate resilience refers broadly to the capacity of social, economic, and environmental systems to cope and respond to climate change, and maintain essential functions and adaptive capacity. Because resilience as a concept captures many complex interactions between equally complex systems, it is challenging to precisely measure directly. Resilience indicators are therefore almost always proxies (Tyler et al., 2016).The box below highlight a number of different dimensions to the concept of resilience.

Box 3: Different dimensions of the definitions of resilience

Ecological: The ability of a system to withstand shock and maintain critical ecological functions.

Socio-ecological: The amount of disturbance a system can absorb, capacity for learning and adaptation, and degree to which system is capable of self-organizing

Social: The ability of groups and communities to cope with external disturbances as a result of social, political, and environmental change.

Community: Linkages between a set of adaptive capacities and a positive trajectory of functioning and adaptation after an external disturbance

Source: Quinlan et al., 2016

Assessing and measuring resilience depends not only on the assessor's underlying conception of the term, but also on the boundaries, properties, and configurations of the systems that are being assessed, and the disturbances being considered (Carpenter et al., 2001). Practically, this means that metrics of resilience will vary according to spatial, temporal, and situational contexts. For example, methods for measuring the resilience of coastal communities in Southeast Asia will be very different for those residing in the Steppes of Central Asia. And in turn, measures of ecological resilience for each of these regions will be markedly different as well.

As a result most resilience measurement frameworks do not explicitly prescribe indicators, but suggest thematic areas and components for which indicators may be tailored depending on the target's context. Annex C gives some more details on those that do include any indicators. Twigg (2009) presents five thematic areas that can be used to measure resilience: governance, risk assessment, knowledge and education, risk management and vulnerability reduction, and disaster preparedness and response. Each of these thematic areas contain a number of resilience components that further guide the selection or development of indicators. Governance for example includes components such as DRR policies and political commitment, institutional mechanisms and legal and regulatory systems.

Similarly, Oxfam's approach to measuring resilience includes themes such as livelihood viability, innovation potential, access to contingency resources and support, integrity of the natural and built environment, and social and institutional capability—each of which can be measured using different indicators based on context (Jeans et al., 2016).

Recent approaches to measuring resilience have focused on subjective measures: measurements that rely on perceptions and self-assessment of individuals rather than precisely defined metrics (Clare et al., 2017). For example, subjective resilience assessments might ask individuals to respond on a Likert scale to statements such as: *"I am confident that my family will have enough rice to eat during the flood season"* (ibid). Proponents of this approach suggest that subjective measures, when incorporated into resilience frameworks, provide a more complete understanding of resilience by including intangible psychological and social factors (Jones & Tanner, 2017).

Some examples of resilience frameworks and the indicators are presented in the table below.

Table 6: Examples of resilience frameworks

Articles	Resilience approaches and indicators	Data and development
(Keating et al., 2017)	List 88 sources of resilience that are each categorized by 5 Capitals (i.e., human, social, natural, physical, financial), 4Rs (redundancy, resourcefulness, rapidity, robustness), ten themes (health, education, assets and livelihoods, food, water, natural environment, etc.) Two perspectives of the system level (community and enabling environment), and five phases of the DRM cycle.	Tool piloted in communities across three countries and at the time of writing it was being tested in communities across additional 8

		country programmes.
(Quandt, 2018)	1. Natural: Size of farmland; diversity of crops; # of livestock), etc. 2. Financial: Salaried? bank account? household belongings; Ownership of farm equipment, etc. 3. Human: # of household members, level of education; health indicators, etc. 4. Social: Family network close by? Extent of access to political influence or power; participation in agriculture or tree planting group? Strength of relationship with neighbours? etc. 5. Physical: road conditions, presence of schools, hospitals, etc.,) Access to irrigation;	Use of secondary data as well as primary data from one country context using sample surveys and interview data.
(Bizikova et al., 2019)	Identifies a range of indicators under the headings: (1) climate change – seasonality and severe weather events; (2) Demographics (e.g., (3) Farm production activities; (4) local market economy characteristics (5) Rural infrastructure and (6) Environmental services. See Annex C for these indicators.	Applied/tested in one country context.
(O'Connor et al., 2017)	State that the key measure of a household's ability to cope in a crisis is its asset wealth, which include natural (land), physical (tools and equipment), human (skills and knowledge), financial (cash and liquid assets), and social assets (norms and values).	Conceptual.
(Wilson & Yaron, 2016)	1) occurrence and severity of shocks; 2.) coping strategies (type and perceived severity); 3.) access to safety nets; 4) days without sufficient food; 5) access to credit; 6) diversification of livelihood; 7) soil and water conservation measures; 8) fertilizer use; 9) access to information; 10) access to medical services; 11) access to safe water.	Based on secondary data.
(USAID, 2018)	Strengthening resilience requires strengthening three overlapping capacities (see Annex C for indicators): *Absorptive capacity* - ability to minimize exposure and sensitivity to shocks and stresses and to take preventative measures and appropriate coping strategies to avoid permanent negative impacts. *Adaptive capacity* - ability to make proactive, informed choices and changes in livelihood and other strategies in response to longer term social, economic, and environmental change; and *Transformative capacity* - governance mechanisms, policies and regulations, cultural and gender norms, infra-structure, community networks, and formal and informal social protection mechanisms that constitute the enabling environment for systemic change Also included in the above mentioned 'sources' for resilience: Social capital; Financial inclusion; Aspirations, self-efficacy, and confidence to adapt; Women's empowerment and gender equality; diversification of livelihood risk; sustainability of natural resources; and access to markets.	Based on secondary data.
(Summers et al., 2017)	Looks at natural environment (extent and integrity); Society (economy, services, characteristics); Built environment (infrastructure); governance (preparedness and response); and risk (losses and exposure). See Annex C for indicators.	Based on secondary data.

(Jacobi et al., 2018)	Formulates the following dimensions of resilience (see Annex C for indicators for each): • Buffer capacity (diversity of crops and breeds, social and physical, natural, human, and financial capital, etc). • Self-organisation (decentralisation, consumption of local produce, interest groups, etc.). • Capacity for learning and adaptation (knowledge of threats/opportunities, reflective and shared learning, use of traditional knowledge, shared vision and feedback mechanisms).	Use of primary data (interview data) from two country contexts.
(Choptiany et al., 2015)	• Level of resilience is determined by indicators of: exposure to disturbance; ecological self-regulation; social self-regulation; functional and response diversity; appropriately connected; globally autonomous, locally independent; spatial and temporal heterogeneity; optimally redundant; coupled with local natural capital; optimally redundant; honours legacy; reflective and shared learning	Conceptual.

In essence, there is no consensus on how to measure resilience primarily because what constitutes resilience varies through time and space. Hence, resilience criteria is highly diverse. A meta-analysis of resilience frameworks and indicators (Schipper & Langston, 2015) looked at 17 sets of indicators of resilience found in internationally recognised resilience frameworks with a view to understanding what these indicators actually convey about resilience. This required a working definition of resilience against which indicators could be assessed; and the authors identified three criteria (i.e., learning, options, and flexibility) that encompass key dimensions of resilience which recur in the literature. In assessing alignment of the indicators with the (above mentioned criteria) and the nature of this alignment, the analysis found that the criteria selected for the analysis were generally well aligned with the indicator sets. Moreover, the analysis also showed that:

- Each framework is strongly influenced by its conceptual entry point and a comparison is only partially possible. Lack of agreement on what resilience means has left the field 'messy' and this does not refer only to variations in how the definition is worded or framed, but to the multitude of 'principles', 'qualities', 'dimensions' and 'characteristics' that go beyond a simple definition and aim to describe what resilience is about. For example, for some sustainable management of agricultural land is a clear indicator of resilience while for others, resilience is driven by governance and institutional changes. These different entry points for analysis make the task of comparing frameworks uneven and makes each framework distinct.

- Resilience to climate change and disaster risk cannot be measured only through indicators of improved livelihoods and well-being, but it cannot be measured without such information, because resilience requires well-being and sustainable livelihoods. For example, numerous indicators that touch on health and general development factors provide a useful context for understanding how successful resilience building is likely to be, but good health alone (not in the context of extreme events or climate change) will not be able to say anything about whether or to what extent the person in question is resilient to extreme events or climate change.

- Indicators need to be used with caution and in some cases their use may be incompatible with the desire to measure resilience. Indicators are only able to indicate, and not to provide scientific 'proof' or detailed explanations of change, partly because they are based upon assumptions about how systems work. For example: which types of crops offer the greatest resilience in an unknown situation of drought, flood or heatwave? Should farmers be planting all their fields or is it best to leave some fallow? Are more formal institutions better or worse than less formal ones in the case of extreme events, given any number of other factors that influence vulnerability? Such questions can only be meaningfully answered when viewed in the boarder context.

5.2 Biodiversity metrics

Biodiversity and ecosystem resilience are linked closely with climate change resilience in many frameworks. Biodiversity changes have proven complex to estimate and understand. While there are negative trends at a global scale such as the substantial losses of vertebrate species, changes at local scales may show large variation, with no clear overall trend. Moreover, different components of biodiversity do not have the same trends over time, and trends differ among taxonomic groups (Yoccoz et al., 2018). Hence, approaches to quantifying ecological resilience have developed slowly and are diverse. They include rapid assessment approaches focused on surveys and stakeholder knowledge of the systems they inhabit. This type of approach is more qualitative, but provides metrics which can be used to assess uncertainty, relative resilience among similar systems, and assess trade-offs among social, economic and ecological components of complex systems (Angeler and Allen, 2016).

Other qualitative approaches include the Resilience Alliance Workbooks, which involve stakeholders in an intense but brief exploration of the drivers of resilience in the systems in question (Resilience Alliance, 2010). While this approach increases awareness of resilience and its drivers, it provides no meaningful metrics, and ignores much complexity.

Significant methodological advances have been made in recent years in ecology, with many approaches, including network analyses, discontinuity analyses and other modelling tools allowing for quantifying attributes of resilience. Much of the social resilience research remains qualitative, and the implementation of quantitative approaches is limited. Despite recent advances, several methodological challenges remain. Current approaches to quantify the resilience of ecosystems are often correlative and limited to the local scale of ecosystems. These approaches often focus on specific organism groups, which allow assessing specific resilience that might not be representative of entire ecosystem at large. Using multiple resilience measurement approaches across organism groups might result in a broader understanding of the general resilience of ecosystems. Correlative approaches in local ecosystems will also need to be complemented with experiments to gain better insight into pattern–process relationships in resilience. Recent resilience research based on correlative approaches have benefitted from the analysis of monitoring data. However, broader assessment of the resilience of landscapes is currently limited by the availability of data that cover the relevant scales of space and time (Angeler & Allen, 2016).

A limited selection of assessment and measurement approaches for ecological resilience in the table below illustrates the range of methods that have been designed for use by experts, managers, and communities for various purposes and under different contexts.

Table 7: Summary of approaches to measure and assess resilience in a variety of socio-ecological contexts

Approach	Focus	General Purpose	Frameworks and methods	Metrics
Resilience Assessment Workbook for Practitioners (Resilience Alliance 2010)	Social-ecological resilience	Understand resource issues from a complex system's perspective and develop strategic management goals	Modules: system boundaries, system dynamics, interactions, adaptive governance, acting on the assessment. Methods: modelling, timelines, scale analysis, scenarios, network analysis, discussion	Attributes of resilience identified, some measured. No use of specific indicators
The Resilience, Adaptation and Transformation Assessment Framework (O'Connell *et al*. 2015)	Social-ecological resilience	Operationalize concepts of resilience, adaptation and transformation in broader global policy domains	Modular framework: Assessment procedure – system description, assessment, adaptive governance and management, stakeholder engagement; indicators for key variables; summary action indicators; meta-indicators	Summary action indicators and meta-indicators of coverage and quality of assessment
A Guiding Toolkit for Increasing Climate Change Resilience (IUCN 2014)	Social-ecological resilience	Guidance on developing climate change-resilient strategies and plans at national, subnational and local levels	Themes: diversity, self-organization and adaptive governance, learning and sustainable infrastructure, technology, participation, information sharing, gender and coordination. Methods: decision support and qualitative modelling	Ranking of 47 qualitative, hierarchical attributes
Community-based resilience analysis (CoBRA), (UNDP 2013)	Development resilience	Quantify results of interventions and measure the ability of households to cope with drought in the Horn of Africa	Sustainable Livelihoods Framework with five categories of capital: human, natural, financial, social and physical. Methods: interviews, focus groups, participatory approach, household economy approach	Community-developed, quantitative indicators linked to five capitals
Indicator framework for assessing agro-ecosystem resilience (Cabell & Oelofse 2012)	Social-ecological resilience	Assess resilience of agro-ecosystems	Resilience attributes linked to specific phases of the adaptive cycle. Multimethod specific to each indicator	Thirteen behaviour-based indicators
Assessing resilience in stressed watersheds (Nemec *et al*. 2014)	Social-ecological resilience	Simplified desktop application for rapid resilience assessment	Properties: ecological variability, diversity, modularity, acknowledgement of slow variables, tight feedbacks, social capital, innovation, overlap in governance, and ecosystem services. Methods: Literature	Nine resilience properties ranking from 1 to 5

			review, rapid prototyping and scoring	
Indicators of critical slowing down (CSD) (Dakos & Bascompte 2014)	Ecological resilience	To detect critical transitions that may be associated with regime shifts	Framework describes a shift between alternate stable states and CSD as system approaches threshold. Various statistical tools and modelling of empirical data	Indicator is statistical signature of CSD
A common analytical model for resilience measurement (FSIN 2014)	Development resilience	Measure resilience in a development context with a focus on food security	Components: construct assumptions, causal framework, indicators and data structure, expected trajectory, data collection, estimation procedures. Variety of quantitative and qualitative methods	Categories of indicators provided, specific indicators depend on context
Framework for urban climate resilience (Tyler & Moench 2012)	Social-ecological resilience	To inform priority interventions as part of a resilience strategy	Elements: systems (e.g. flexibility and diversity), social agents (e.g. responsiveness, capacity to learn) and institutions (e.g. rights and entitlements, decision making). Methods: vulnerability assessment, shared learning dialogues	No use of specific indicators

Source: Adapted from Quinlan, et.al., (2016).

5.3 Concluding remarks

Resilience has become a buzzword in the last decade or so, and despite the flourishing research field, the original definition remains probably the most useful, as given by Holling (1973) as "…*the amount of disturbance that a system can withstand before it shifts into an alternative stable state."* The term 'resilience' has since then become so loose and imprecise that it is often used in a normative sense (Brand and Jax, 2007), as if resilience were a desirable quality of systems. But even systems in highly undesirable states, such as macro-algae dominated reefs, or parts of the urban landscape caught in poverty traps can be highly resilient, which is to say they can withstand attempts to transform them into different (desirable) states (Angeler and Allen, 2016). It is this misuse and confusion around the concept of resilience that has made operationalising it for application and management purposes difficult.

In spite of the development of resilience theory across multiple disciplines, methodological and theoretical knowledge gaps related to quantifying ecological resilience remain. Current approaches tend to focus on specific organisms at a local scale, which might not be representative of ecosystem wide resilience. Broader assessment of landscape level resilience is very often hampered by lack of spatial and temporal data, which in turn is due to absence of available funding for ongoing monitoring activities. Theoretical challenges limiting quantitative resilience research include fuzziness around the much recommended adaptative management approach, which is defined differently for different context's, thus making its meaning and potential for operation alisation unclear.

The way forward would include additional conversations between teams who are involved in indicator development; acknowledging and detailing the role played by, and delineating the relative importance of, the various selected indicators vis-à-vis the development scenario for a given situation; and being aware of the limits that come with taking snapshot measurements in time of dynamic realities. While indicators have their short-comings, their development requires a process of reflection and deliberation on what is truly required for resilience. Thus, even if the indicators themselves fail to be useful, the path toward their development, provides a robust theoretical platform on which to build more knowledge (Schipper and Langston, 2015).

6 Biodiversity hotspots in Asia

In the late 1980s, Myers (1988,1990) first penned the term 'biodiversity hotspots' and classified 25 globally as regions of rich endemic biodiversity, facing high level of threats for species and habitat loss. Conservation international further built on this work to identify 36 hotspots across the world, 7 out of which are located in the Central-South- South East Asia region[17]. This research has shown that most of nature's diversity lies on a relatively small part of the Earth's surface, with the implication that it is perhaps more efficient to focus the limited resources for conservation efforts on these hotspots (Jenkin and Pimm, 2000)

Other researchers have built on the hotspot concept to identify the interlinkages of biodiversity with multiple socio-economic and anthropogenic pressures such as climate change, poverty, livelihoods and social interactions. A review of these stressors identifies that deforestation, illegal hunting and trade, invasion of alien species, human intrusion and climate change are some of the biggest threats for species extinction and ecosystem imbalance in the biodiversity hotspots of Asia Pacific region.

However, the research available on hotspot conservation in Asia is limited by inconsistent quantitative data on rates of degradation, lack of real-time data on biodiversity status and only ad-hoc studies on emerging pressures. Furthermore, National Biodiversity Strategy and Action Plans reviewed for different countries of the region do not in general specify targeted strategies for these regional biodiversity hotspots. While the countries are taking several measures for biodiversity conservation in different protected areas, a targeted landscape approach is needed to deal with the emerging anthropogenic and development pressures in the hotspot region. The landscape approach enables development, integration of sectoral interests while protecting and enhancing ecosystems and their services.

6.1 The definition of biodiversity hotspots

Biodiversity hotspots are regions of rich endemic biodiversity which are facing a high level of threat of species and habitat loss. Myers et.al.(2000) defined biodiversity hotspots as areas that contain at least 0.5% of the world's plant species as endemic (with the understanding that vascular plants are essential to all forms of animal life). This research identified 25 hotspots around the world comprising 1.4% of the earth's land surface and harbouring 44% of vascular plant and 35% of animal vertebrate species. Myers research since the late 1980s set the foundation for all subsequent research and has been built on in particular by organizations like WWF and Conservation International.

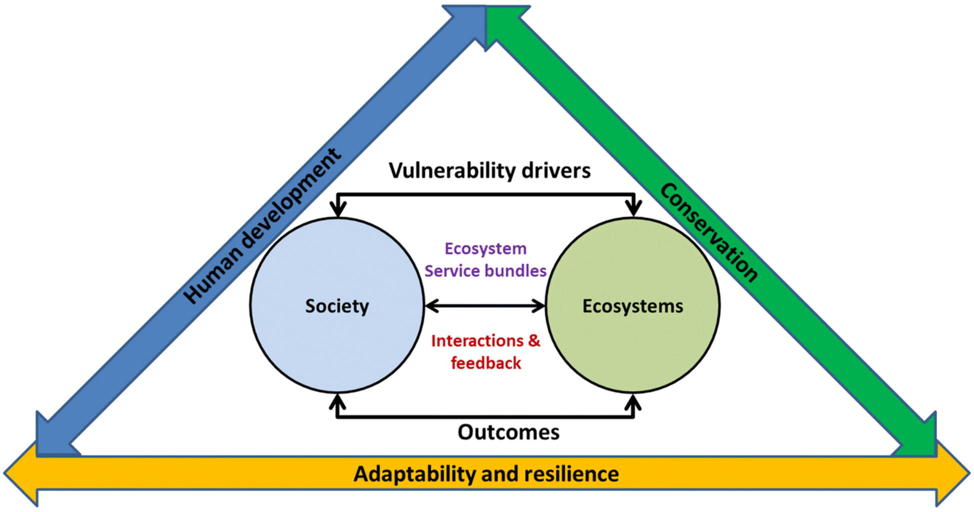
Recent research further defines the concept of hotspots and integrates it with concerns relating to multiple stressors including climate change and disaster risks, social-ecological resilience, resource dependent livelihoods and anthropogenic pressures on

[17] These include the Mountains of Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan and Turkmenistan); Wallacea (Indonesia, Timor Leste); Eastern Himalayas (India, Nepal, Bhutan); Western Ghats (India, Srilanka); Phillipines; Sundaland and Nicobar Islands (India, Indonesia, Malaysia, Thailand, Singapore, Brunei) and Indo-Burma (India, Bangladesh, Myanmar, China, Vietnam, Laos, Cambodia).

fragile ecosystems (Ostrom, 2009; Bennett et.al. 2009; Kilroy, 2015). These integrated and transdisciplinary approaches are necessary to understand the complex drivers of habitat loss and degradation as well as suggest synergistic responses to influence policy and practice (Khan and Cundill, 2019).

Khan and Cundill (2019) have built on Myers ecological concept to develop a 'Hotspot 2.0' approach. This explores the interrelationships between human and natural systems and helps to address the multiple stresses on biodiversity and society.

Figure 2: Hotspots 2.0: Coupling Social Ecological Systems with multiple stressors and opportunities for action



Source: Khan and Cundill (2019)

A key tenet of the biodiversity hotspot thesis is that conservationists cannot support all species under threat, due to a lack of resources. It offers a way of prioritising the limited funding available: how to get the biggest return per scarce dollar available (Myers, 2003). Myers et. al (2000) estimated that it was possible to safeguard the initial 25 hotspots identified with just one-twentieth of the $10 billion spent annually over 5 years. Pimm et.al. (2001) argued that a one-time cost of $25 billion would be required to save the hotspots. Other research has also tried to develop a finer scale to define conservation priorities given the hotspots are too large to be practical to protect in their entirety (Jenkins and Pimm, 2020). The multi-donor Critical Ecosystem Partnership Fund (CEPF) has followed this hypothesis through massive targeted investment in a few hotspots and within those identify priority needs and areas (see box below).

Box 4: Critical Ecosystem Partnership Fund for hotspot conservation research and planning

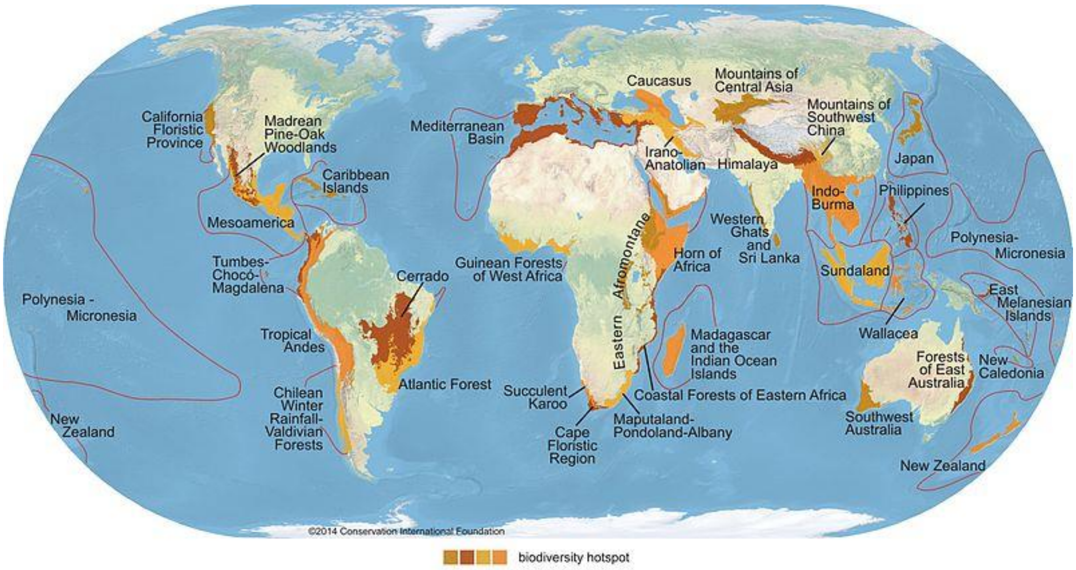
Adding to this body of theoretical research, the multi-donor Critical Ecosystem Partnership Fund (CEPF) supports the development of biodiversity conservation strategies in biodiversity hotspots through research and conservation projects. The partnership has given $232 million of grants to conserve more than 1,250 species in the IUCN Red List of Threatened Species and strengthened the management and protection of 46.5 million hectares of Key Biodiversity Areas (CEPF, 2020).

The action research initiative provides grants for developing ecosystem profiles as well as build long term local conservation leadership. For example, in the Indo-Burma hotspot it has awarded 126 grants, and invested $15.8 m between 2013-20 (CEPF, 2020). This included a grant to protect the Critically Endangered Burmese roofted turtle, thought to be virtually extinct, but through captive breeding, community outreach and other measures, these turtles are slowly being reintroduced (CEPF, 2018).

6.2 Key biodiversity hotspots in the region

Building on Myer's concept and initial list, Conservation International continues to review global assessments (Mittermeier et al. 1999, Mittermeier et.al, 2004 etc) and expand the list which currently stands at 36 biodiversity hotspots across the world. The most recent hotspot to be added was the North American coastal plain (Noss et al, 2015). These are regions which meet two criteria: It must be irreplaceable and have at least 1,500 vascular plants as endemics, meaning it has a high percentage of plant life found nowhere else on the planet; and it must be threatened and have at least 30% or less of its original natural vegetation. Many exceed these benchmarks, for example, in Indo-Burma, only 5 percent of the hotspot's natural habitat remains in relatively pristine condition. The map given below identifies the biodiversity hotspots[18], home to around 2 billion people including some of the world's poorest (CI, 2020).

Figure 3: Conservation International's Biodiversity Hotspots.



Conservation International's biodiversity hotspot atlas identifies 7 of the biodiversity hotspots as being in the Central-South- South East Asia region. The region has biodiversity rich megadiverse countries also characterised by high population density, including some of the world's poorest populations directly dependent on healthy ecosystems for their livelihood and well-being (CEPF, 2020). The biodiversity hotspots in Asia represent diverse ecosystem landscapes, preserve natural capital and provide ecosystem services to indigenous and vulnerable populations directly or indirectly dependent on this. These diverse hotspots and the countries they cover are summarised in the table below.

[18] The map includes only 35 of the hotspots, without the latest hotspot, the North American coastal plain.

Table 8: Summary of biodiversity hotspots in Asia

Biodiversity hotspot	Country	Salient features	Key drivers of degradation
Mountains of Central Asia	Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan and Turkmenistan	Asia's two major mountain ranges: the Pamir; and the Tien Shan. Glacial melt water is the source of 80 percent of total river runoff in the region	Habitat change, poaching, excessive hunting and collection of plants, overgrazing, human-wildlife conflict, pollution and invasive and alien species
Wallacea	Indonesia, Timor Leste	Forms the heart of the western Pacific area known as the "Coral Triangle", comprising of 1,680 islands with a population of 30 million people	Small scale and illegal logging, unsustainable small-scale fishing, hunting, industrial agriculture and forestry, expansion and intensification of smallholder agriculture/ livestock
Eastern Himalayas	India, Nepal, Bhutan	Home to endangered species such as Bengal Tiger, Asian Elephant and Red Panda. Tribal and ethnic diversity with more than 500 ethnic groups. Stretches of understudied and inaccessible terrain.	Habitat loss and degradation, poaching, mining, over grazing, non-timber forest product extraction, climate change, conversion of forests and grasslands for agriculture, overpopulation, tourism
Western Ghats	India, Sri Lanka	6% of India's land with 30% of country's biodiversity; some part of the region traditionally conserved as sacred groves	Livestock grazing, illegal hunting, human-wildlife conflict, extraction of forest products, fodder and fuelwood extraction, tea/coffee/rubber plantation
Philippines	Philippines	7100 islands in the Pacific Ocean, rich biodiversity of coral reefs, amphibians and other flora/fauna species	Extractive industries (mining, logging, fishing), increased population density, urbanisation, conflicting land use policies
Sundaland and Nicobar Islands	India, Indonesia, Malaysia, Thailand, Singapore, Brunei	a group of some 17,000 islands stretching 5,000 kilometers; high mountain ranges, volcanoes, plains, lakes, swamps and shallow coastal water	Forest destruction (logging, oil palm and rubber cultivation), forest fires, illegal hunting and wildlife trade, road construction and mining
Indo-Burma	India, Bangladesh, Myanmar, China, Vietnam, Laos, Cambodia	More than 300 million people live in Indo-Burma, more than any other hotspot; poverty alleviation and biodiversity conservation inextricably linked	Hunting and trade of wildlife, agro-industrial plantations (eucalypts, rubber, pine, tea, coffee and oil palm), hydropower dams, agriculture encroachment, infrastructure and logging

Source: CEPF (2020)

Box 5: Mountains of Central Asia Biodiversity Hotspot

The Mountains of Central Asia Biodiversity Hotspot consists of two of Asia's major mountain ranges, the Pamir and the Tien Shan. It covers 860,000 square km and parts of seven countries: south-eastern Kazakhstan, most of Kyrgyzstan and Tajikistan, eastern Uzbekistan, western China, north-eastern Afghanistan, and a small mountainous part of south-eastern Turkmenistan. It is home to 1,500 endemic plant species and 53 endemic species of mammal, bird, reptile, amphibian, and freshwater fish, meaning they occur nowhere else in the world. Of the approximately 6,700 species occurring in the hotspot, 68 are classified by the IUCN as globally threatened.

The region is also home to about 64 million people, and there are major economic and social pressures on the hotspot, including: economic growth in general (with pockets of economic slowdown), infrastructure development, and instances of local conflict and unrest. Many of the key biodiversity areas sit across and along country boundaries, meaning bilateral or regional cooperation is required.

Source: CEPF (2017)

6.3 Socio-economic benefits of biodiversity hotspots

Biodiversity hotspots provide invaluable ecosystem services for human life, including food production systems, stable natural hydrological cycles, fertile soils, carbon storage and maintenance of biological food chains (CI, 2020). There is a rich body of research documenting the socio-economic benefits of biodiversity and costs of degradation in specific locations and for specific ecosystems. For example, Sharma et.al (2019) have estimated that in the southern plains of Nepal between 2001 and 2016 the loss of forests, water bodies and agricultural land reduced the value of the ecosystem by $11 million. One early influential global study estimated the economic value (most of which is outside the market) of 17 ecosystem services for 16 biomes based on both published studies and new calculations as $33 trillion per year (Constanza et.al., 1997). A recent comprehensive global study has estimated that ecosystem services provide benefits of $ 125-140 trillion per year, more than one and half times the size of global GDP (OECD, 2019).

One of the underlying drivers of the Convention on Biological Diversity (CBD) was that at least 40 percent of the world's economy and 80 percent of the needs of poor people are derived from biological resources (CBD, 1992). A comprehensive knowledge review commissioned by the CBD of poverty and conservation showed that the poor do depend disproportionately on biodiversity for their subsistence needs, and that conservation can be a route out of poverty in some circumstances (IIED, 2010). Turner et.al (2012) used modelling to estimate the value of biodiversity to the poor, both through direct benefits and payments to those stewarding natural habitats. The aggregate benefits were valued at three times the estimated opportunity costs and exceeded $1 per person per day for 331 million of the world's poorest people (Turner, et.al., 2012).

However, biodiversity conservation is often not designed to deliver poverty reduction benefits, and the positive impacts can be limited (IIED, 2010). In addition, there is research on the two-fold relationship between conservation and poverty, on one hand poverty can be a significant constraint to conservation and on the other hand conservation is an important component to the alleviation of long-term poverty (Fisher and Christopher, 2007; Andams et.al, 2010; Adams et.al., 2004). Some research argues that the assumption of win-win solutions for conservation and biodiversity are exaggerated (McShane and Newby, 2004; Salafsky, 2011). Biodiversity hotspots contain a substantial fraction of the world's poor, for example 21% of the world's malnourished children lived in hotspots in 2005 (Mittermeier, 2011). As such, complex relationship between poverty and biodiversity is of particular relevance to hotspots.

Box 6: Valuation of ecosystem services of biodiversity hotspot, Western Ghats

As a part of 'The Economics of Ecosystems and Biodiversity – India Initiative (TEEB-TII)' implemented by the Government of India, researchers identified the value of biodiversity and ecosystem services (forests, inland wetlands and costal and marine ecosystems) to help integrate them into developmental planning.

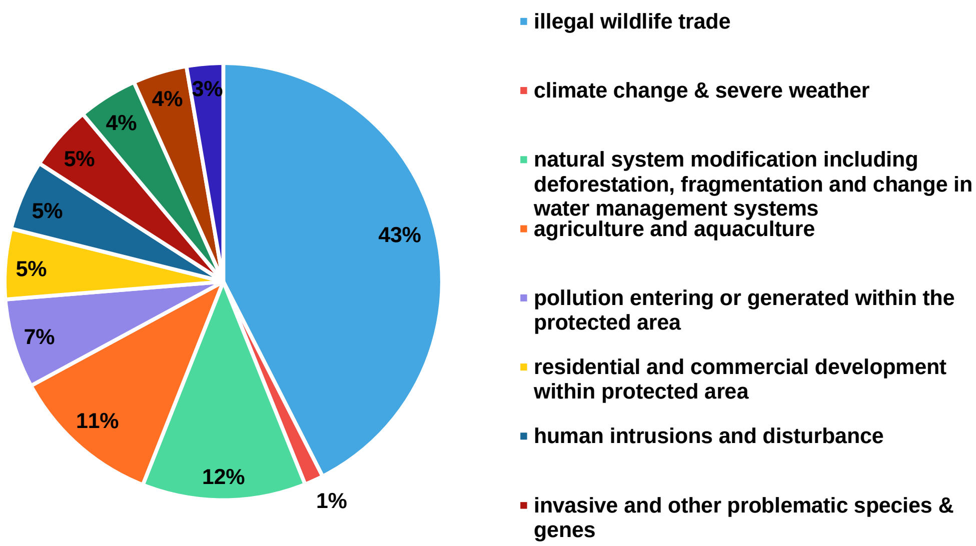
The study included an evaluation of the ecosystem and provisioning services of Western Ghats, a biodiversity hotspot- watershed home to around 50 million people. It harbours around 4,000-4,600 species of flowering plants of which 2,100 are endemic. It forms the major watershed in India, with 58 major rivers originating from it. For example, in the Western Ghats, the benefit from carbon sequestration in Uttara Kannada district (7,819 sq km) amounts to $ 126m annually and the value of timber is up to $ 1,592) per hectare per year. The fuelwood contributed 16% to 37% and non-timber forest products (NTFP) contributing 40% to 63% of the income among gathering households. The value generated by tourism in Dandeli and Anshi Protected Area was US$ 189m per year for the year 2014.

Source: MoEFCC and GIZ (2014)

6.4 Rates and drivers of degradation

Rapid urbanisation, deforestation, mining, hunting and poaching, climate change and population pressure are some of the key drivers of degradation in biodiversity hotspots. The figure below presents the threats in protected areas in Asia in terms of their contribution to the causes of degradation, suggesting that illegal wildfire trade is the biggest contribution (43%). These factors have led to habitat conversion, degradation, fragmentation, species introduction and overexploitation, all leading to high rates of degradation and biodiversity extinction in the hotspots.

Figure 4: Most common threats to protected areas in Asia



Source: Reproduced from Juffe-Bignoli et.al. (2014) based on data from the Protected Area Management Effectiveness' (PAME) database which records threats to 500 protected areas in 12 countries in Asia between 2000 and 2009.

Section 7 discusses in detail the connection between climate change and biodiversity. Some of the other key drivers of degradation are discussed below:

***Deforestation and fragmentation*:** Land grabbing, encroachment in protected areas, logging and agriculture demand for palm oil, rubber and wood pulp are some of the drivers for deforestation Asia, particularly in the South East Asian region. In South East Asian countries, tree plantation and deforestation pose some of the biggest threats to biodiversity loss, with the region witnessing highest levels of deforestation (Sodhi, 2019). Countries such as Philippines and Indonesia have already lost over half their original forest cover with projections of as much as 98% loss for some regions in the coming decade (Hughes, 2017). Between 1973 and 2009, countries such as Cambodia, Laos and Vietnam have lost up to 5.2%, 7% and 4% respectively (ibid.). In Indonesia, 16% of the total primary forest lost (6.02 million hectares) during 2000-2012 occurred within conservation and protection forests that prohibited clearing (Juffe-Bignoli, 2014). In mountain hotspots such as the Eastern Himalayas and Central Asia mountains, overgrazing has also led to degradation of fragile steep slopes (CEPF, 2020).

Box 7: Key drivers of degradation in the Western Ghats

The Western Ghat Ecology Expert Panel, led by renowned Indian ecologist Prof. Madhav Gadgil assessed the key drivers of degradation in the Western Ghats and provided recommendations for regulating development activities the region. The Gadgil Commission identified Ecologically Sensitive Areas and assigned 3 levels of ecological sensitivity to different regions in the Western Ghats. The report identified sectoral guidelines for different zones and provided recommendations for restrictions and regulations in mining, dam construction and other developmental activities. The commission recommended an inclusive governance regime for sustainable development, recognising the legal provisions for environmental protection and the democratic devolution of the democratic process

Source: Gadgil (2014).

***Illegal trade and hunting*:** The United Nations Office on Drugs and Crime (UNODC) report (2019) states that illegal wildlife trade is the fourth most profitable criminal trafficking trade in South East Asia with an estimated 23 billion USD annually. This illegal trade is driven by demand for meat, medicines, pets and 'high value' wildlife products such as rhino horn and elephant tusks. Uncontrolled hunting pressure within protected areas has led to dramatic population declines and extinction of several globally significant wildlife species. Weak governance regimes associated with poor law enforcement have further increased the vulnerability of protected areas to wildlife exploitation (UNODC, 2019; Harrison et.al., 2016). The Indo-Burma hotspot holds remarkable endemism in freshwater turtle species, most of which are threatened with extinction, due to over-harvesting and extensive habitat loss (CEPF, 2011).

***Urbanisation and human intrusion*:** Cities in South and South East Asia are some of the most densely populated and fastest growing regions in the world. Asia is home to 54% of the world's urban population with countries such as India harbouring the fastest growing megacities and urban agglomerations. A megadiverse country with 4 biodiversity hotspots, India is projected to add 416 million urban dwellers by 2050 (UN DESA, 2018). India's real estate sector is expected to contribute 13% to the country's GDP by 2025 with environmental footprint accounting for 40% energy use, 30% raw material use, 20% water use and 20% land use; generating 30% of solid waste and 20% of water effluents (WEF, 2020).

In South East Asia, distances between urban areas and protected conservation is shrinking gradually. In 1995, 50% of protected areas in Southeast Asia were within 57 km of cities, by 2030, this distance is likely to shrink by 30% to 40 km (Braimoh et.al. 2010). With these drivers of degradation, maintenance of protected areas and green spaces in cities play an important role in providing refuge to native species and migrating wildlife (Aronson et.al. 2014).

6.5 Integration of hotspot conservation in national plans

The Convention on Biological Diversity (CBD) mandates each country to develop a National Biodiversity Strategy and Action Plan (NBSAP) intended to define the current status of biodiversity, threats leading to its degradation and the strategies and priority actions to ensure its conservation within the socio-economic development framework of the country. The CBD's Strategic Plan for Biodiversity (2011-20) identifies 20 time-bound measurable targets (Aichi Targets) to be met by 2020. While, Aichi Target 12 (prevention of extinction of threatened species) directly states the conservation of hotspots, other Aichi targets indirectly guide the countries to improve the status of hotspots by safeguarding ecosystems, species and genetic diversity.

Having reviewed the NBSAPs of different countries in the region, it is concluded that these country plans do not specify targeted strategies for regional biodiversity hotspots located in their geographical boundaries.

While NBSAPs of countries such as India, Bhutan, Indonesia, Philippines and Vietnam identify biodiversity hotspots as critical regions of conservation, other countries fall short of any mention of biodiversity hotspots in their action plans. India's sixth national report to the CBD makes special mention of the actions taken under National Mission for Sustaining the Himalayan Ecosystems and The Economics of Ecosystems and Biodiversity India Initiative for conservation of the biodiversity hotspots- Eastern Himalayas and Western Ghats respectively (GoI, 2018). The remaining countries in the region, do identify strategies for nationally recognised protected areas, however, do not provide any significance to the hotspot concept in their national biodiversity plan.

While the countries are taking several measures to follow for biodiversity conservation in different protected areas, a targeted landscape approach is needed to deal with the emerging anthropogenic and development pressures in the inter-country geographical boundaries of biodiversity hotspot region. Landscape approach considers a hotspot region as an integrated management system and recognises the different aspects of its multifunctionality, inter-country geography and rights to land use and resource access (WRI, 2020). The landscape approach enables development, integration of sectoral interests while protecting and enhancing ecosystems and their services (Scheyvens, et.al. 2017).

The research highlights that conflicting policies, weak governance structure and law and enforcement issues aggravate the degradation in many biodiversity hotspots across Asia- Pacific (CEPF, 2011; CEPF, 2017). It therefore seems crucial to integrate hotspot conservation in economic, social and poverty alleviation policies. Lim (2015) suggests 12 governance criteria for effective transboundary conservation, including political buy-in, equitable distribution of the costs and benefits of transboundary conservation etc[19].

Lastly, from the review of national plans, there appears insufficient monitoring and evaluation of drivers and pressures of degradation. In particular: periodic monitoring of spatial changes in hotspot region, real-time monitoring of biodiversity status, analysis of threatened species, assessment of ecosystem services and evaluation of direct and emerging drivers of degradation.

6.6 Concluding remarks

The biodiversity hotspot concept has developed since the late 1980s as a well-researched approach to prioritising the limited resources for conservation. A comprehensive global assessment process continues to inform the updating of the list of hotspots. However, there are some limitations to the research available on biodiversity hotspots.

The majority of the research on biodiversity hotspots in Asia focuses on specific species, taxonomic groups and ecosystems (Basnet, et. al. 2019). A review of research studies conducted on the Eastern Himalayan region identifies that most studies focused on species (73.6%), followed by ecosystems (25%) and genetics (1.4%). Mammals were the most studied taxa (22.6%), followed by arthropods (15.6%), angiosperms (14.8%), insects (13.4%), and birds (10.8%)(ibid).

There are some research articles that study the drivers of degradation at a particular point of time in the different biodiversity hotspots (Subramanian, 2011; Braimoh et.al, 2010; Hughes, 2017). However, there is a lack of quantitative data across landscapes and countries on rates of degradation and information on emerging pressures. The metrics, methodologies and sample size for measuring the rates of degradation are inconsistent and vary for different research studies. This inconsistency makes it difficult to draw comparisons in the state of environment across different hotspots. Lastly, some hotspots such as Mountains of Central Asia, Sundaland and Nicobar island appear to be relatively less documented compared to the others.

[19] The 12 criteria for effective transboundary biodiversity conservation include: (1): Engages each level of political organization; (2): Has political buy-in; (3); Costs and benefits of transboundary conservation are equitably distributed; (4): An integrated ecosystem approach which incorporates available science is applied; (5): The objective of conservation is explicit; (6): Good governance is practiced; (7): Clear success indicators for ongoing monitoring and evaluation exist and adaptive management is practiced; (8): Existence of rules and legal instruments that enable the process; (9): Designated institutions are identified at each level of organization and vertical and horizontal linkages are established across all levels; (10): Operations in consideration of capacity; (11): Complexity is recognised and appropriate funding is secured; (12): Dispute resolution mechanisms exist.

7 Synergies and trade-offs between biodiversity conservation and climate resilience

There is a growing body of literature recognising the interlinkages between ecosystem services, biodiversity conservation and climate change actions. Natural resources and biodiversity are threatened by the impacts of climate change but also provide valuable ecosystems services for climate adaptation and mitigation. Concepts such as Nature-based Solutions (NbS) have developed as specific integrated approaches to biodiversity conservation and adaptation (see Chapter 8 for a detailed discussion on these two approaches). Reducing emissions for deforestation and degradation (REDD, forest, wetland and mangrove carbon stocks have further been recognised as mitigation measures provided by biodiversity conservation measures.

There are numerous documented examples from Asia of measures that have demonstrated a synergistic impact of conservation based resilience, for example Marine Protected Areas (Philippines, Indonesia), the NABARD WADI agroforestry model (India), mangrove rehabilitation and coastal green belt initiative(Bangladesh), sustainable agriculture and land use management (Central Asia) and ecosystems protecting road infrastructure (Nepal). However, a lot of these initiatives are donor driven with limited time-frames and financial sustainability. The literature review identified the need to create strong national frameworks to embed biodiversity and ecosystem services into poverty eradication and sustainable development agendas.

There are also some examples in the literature of the trade-offs between climate actions and biodiversity conservation. Trade-offs include between long-term and short-term benefits of different measures, equity and socio-economic dimensions, choices for land use, and cost versus benefits.

7.1 Biodiversity conservation measures in Asia

As signatories to the CBD's Strategic Plan for Biodiversity (2011-22), countries in the Asia region are taking active measures for biodiversity conservation. According to the 'State of Biodiversity in Asia and the Pacific' report, the region is witnessing a steady increase in the Protected Area coverage since 1990, which now adds upto 13.7% of the terrestrial region and 11.9% of the marine and coastal region in the Asia Pacific (UNEP-WCMC, 2016). There is a growing recognition of trans-boundary collaboration for protecting areas of high biodiversity conservation value (ibid).

The development of National Biodiversity Strategies and Action Plans (NBSAPs) has been a key policy tool for achieving Aichi Biodiversity Targets for Asian countries (ibid). The table below summarises biodiversity conservation measures being undertaken in some of the countries across the region.

Table 9: Summary of conservation measures in a sample of countries in Asia

Country	Conservation Measures	Policy initiatives

Nepal	• 20 Protected areas established: 23.23% area of the country • Implementation of conservation plan for species such as tiger, rhino, red panda etc. • Initiatives to enhance international cooperation to curb illegal trade • Systematic monitoring of wildlife populations • Implementation of participatory forest management programmes • Reclamation of encroached forest areas, afforestation and reforestation programmes	• Forest Policy (2015) • Forestry Sector Strategy (2016-2025) • Nepal Biodiversity Strategy and Action Plan (NBSAP) (2014-2020) • Climate Change Policy (2011) • National Framework on Local Adaptation Plan for Action, 2011 • National Wetlands Policy (2012) • National Land Use Policy (2012)
Bhutan	• Management of Protected Area (increased from 26.23% in 1997 to 51.44% in 2008) • Implementation Species conservation plan for species such as Bengal tiger, snow leopard etc. • South Asia Wildlife Enforcement Network (SAWEN) initiative to counter trans-boundary illegal wildlife trade • Development of national biodiversity information system • Maintenance of national crop and gene banks • Development and implementation of Integrated Conservation and Development Programs • Implementation of programs and development of legislations to reduce the rate of deforestation, minimize loss of land for development (urbanization, roads, and industries) and reduction of land for mining and quarry.	• National Forest Policy (2011) • Water Act of Bhutan (2011) • National Environment Protection Act (NEPA) (2007) • Biodiversity Act of Bhutan (2003)
Uzbekistan	• Improvement of the system of Protected Areas aiming to improve coverage from 1.79% to 10% of country's area) • Creation of ex-situ nurseries for rare and endangered species • Implementation of 4 yearly medium-term National Environmental Action Programmes (2 billion USD allocated for the implementation of 2013-17 EAP) • Reforestation and protective forest-growing (sowing, planting, assisting in natural reforestation of degraded forest lands) • Implementation of political, legislative and institutional arrangements for integration of the system of biodiversity conservation into oil-and-gas sector • Programme of state monitoring for natural environment	• Programme on establishing of PA system • National Red Data Book • Environment Protection Policy • National Environment Action Plan • National Forest Policy • National Programme for Combating Desertification, Land Degradation and Drought • National Programne for Forestry Development
Philippines	• Mangrove reforestation efforts (mangrove	• Wildlife Resources

	• cover increased from 0.247 million ha in 2003 to 0.311 million ha in 2012) • Combatting Environmental Organized Crime in the Philippines • Integrated Approach in the Management of Major Biodiversity Corridors in the Philippines • TEEB initiative for valuation of ecosystem services in selected bay regions • Coral Reef Visualization and Assessment (CoRVA) and National Assessment of Coral Reef Ecosystems	Conservation and Protection Act of 2001 • Act to Prevent, Deter and Eliminate Illegal, Unreported and Unregulated Fishing (2015) • Sustainable Forest Management Policy • Climate Change Act (2009)
Cambodia	• Management of protected area system (currently 26% of the country's land) • Development of elephant corridors • Action plans for Mekong Giant Fish, Tiger, Dolphin and Elephants • Prevention programs for invasive alien species • Recover species and populations. Reintroduction of captive-bred species to re-establish populations of endangered or rare plants and animals in the original habitat is necessary	• National Green Growth Roadmap (2013-30) • 2008 Protected Area Law • 2007 Law on Land and Water Resource Management • 2002 Forestry Law
Pakistan	• Billion Tree Afforestation Programme (350,000 hectares of forests and degraded lands are being restored under this initiative) • Green Pakistan Programme (target of planting and regenerating 100 million plants through different afforestation, plantation and natural regeneration activities) • Rehabilitation of Indus Delta Mangroves	• Environment Protection Act (1997) • National Environmental Policy (2005) • National Climate Change Policy (2012) • National Sustainable Development Strategy, • Pakistan Trade Control of Wild Fauna and Flora Act, 2012 • National Forest Policy (2015)
Vietnam	• Conducted basic surveys of marine species that have economic value; built a database of natural resources and marine environments - Planned a national marine protected area system, under which 9 marine protected area have been established. • Some national parks have built the sample storage facilities, botanic garden and published many documents on biodiversity. • 50 aquatic lineages and 60 aquatic varieties have been preserved till date. • Establish, manage, develop and sustainably use 16.24 million hectares of land for forestry; - Increase the percentage of forest land to 42-43 percent by 2010, and 47 percent by 2020 (annual increase reported)	• Law on Forest Protection and Development, 1991 (amended in 2004) • Land Use Law 1993 (amended in 1998, 2003 and 2013) • Law on Environmental Protection, 1993 (amended in 2005 and 2014) • the Water Law, 1998 (amended in 2012) • Law on Fisheries, 2003. Law on Biodiversity, 2008

Source: Compiled by the author based on a review of national policy documents.

However, despite these efforts, important areas of biodiversity in Asia and the Pacific continues to decline. A combination of human induced factors such as deforestation and forest degradation, pollution, invasion of alien species, illegal trade of biodiversity, wildlife products and climate change impacts are negating the conservation efforts undertaken by countries (State of Biodiversity in the Asia and Pacific Report, 2016).

The region has particularly underperformed in achieving the Aichi biodiversity targets 4 (sustainable consumption and production) and 10 (habitat loss reduced) (ibid). Many countries in the region are greatly increasing their production and the global impact of the region in terms of measured human footprint is increasing. Furthermore, considerable loss of tropical forest habitat – particularly to palm oil and other plantations in the South East Asia part of the region has contributed to rapid habitat loss in the region (ibid).

There are also a number of policy and planning challenges contributing to the rates of decline, including:

Ad-hoc funding: A rapid review of NBSAPs in Asia suggests that a lack of funding and resources is a critical challenge for sustained biodiversity conservation. A lot of the initiatives appear to be donor driven with limited time-frames and financial sustainability. A regional research initiative has stressed the importance of creating strong national frameworks to embed biodiversity and ecosystem services into national poverty eradication and sustainable development agendas (IPBES, 2018).

Limited monitoring of progress: Another recurring constraint is the lack of information and data to accurately assess the status, trends, risks, threats and conservation needs for biodiversity in the Asia Pacific region (UNEP-WCMC, 2016).

Constrained by governance units: High population densities and intense development pressure, also necessitates the urgency of taking a landscape or ecosystem approach to conservation planning (Shepherd, 2008). Promoting participatory land-use planning and promoting conservation in multiuse landscapes helps to balance the priorities of both conservation and development in land-use planning (ibid).

7.2 Synergies between climate change action and biodiversity conservation

There is a growing body of literature recognising the interlinkages between ecosystem services, biodiversity conservation and climate change actions. The IPCC presented their first technical paper on the subject in 2002 and have since been consistently reviewing available literature including for specific eco-systems, most recently in the 2019 Special Report on Climate Change and Land (IPCC, 2002; IPCC, 2019). Numerous research studies not only highlight the impacts of climate change on biodiversity, but also assess the role of ecosystem services as a response to climate change (IPBES, 2018; Campbell et.al. 2009; IPCC, 2019; SCBD, 2003).

The synergies between climate change and conservation has also been recognised by intergovernmental bodies including the World Summit on Sustainable Development, the CBD, and the UNFCCC. The CBD have stressed the contribution to tackling climate change of Aichi Target 10 (the reduction of anthropogenic and climate change pressures on ecosystem) and Target 15 (the restoration of ecosystems and enhanced resilience).

As the research available has increased, the IPCC has been more confident in reporting the links between climate change and biodiversity conservation. For example, compared to the AR4 report, the IPCC AR5 presents higher level of confidence in attributing the impacts of climate change at species and ecosystem level (IPCC, 2014). These changes include: increasing vulnerability, exacerbating existing pressures, changing species appearance, and altering the composition of ecosystems (ibid). For example, there are 380-620 million people living within areas which experienced desertification between the 1980s and 2000s, a high proportion of which are in South and East Asia, the Sahara region and the Middle East (IPCC, 2019).

The IPCC has also assessed the growing literature on the synergies between biodiversity conservation and climate change adaptation/mitigation opportunities. AR5 presents a number of options to reduce the vulnerability of biodiversity to the negative impacts of climate change and use natural ecosystems in reducing greenhouse gas emissions. These can be broadly categorised as i) actions to help species and ecosystems adapt to specific climate change impacts; ii) ecosystem-based approaches to adaptation; and iii) ecosystem-based approaches to mitigation (IPCC, 2014). Some of these Nature-based Solutions (NbS) to build resilience are discussed in more detail in Section 8.

The table below identifies some examples to elaborate the synergies in conservation and climate actions:

Table 10: Examples of synergies between conservation, adaptation and sustainable development

Conservation measure	**Ecological benefits**	**Socio-economic benefits**	**Climate adaptation-mitigation benefits**	**Examples from the region**
Agroforestry, adaptive forest management practices	Soil and water conservation; increased biodiversity, restoration of ecological ecosystems; sustainable conservation practices in buffer zones of protected areas	Food security, diversified sources of agriculture and livelihood; protection from heat waves	Increase in adaptive capacity due to higher farm returns and reduced cases of migration; climate impacts on crop production buffered	NABARD Wadi Agroforestry, India (Development Alternatives) Agriculture and sustainable land management, Tajikistan (Dazé, 2016)
Mangrove, coastal biodiversity restoration, wetland conservation	Protection of natural watershed, improved habitat quality, reduced fragmentation, habitat maintained for diverse fish and bird	Sustainable fishing; avenues for tourism; availability of clean water; provision of nursery grounds and aquaculture; flood drainage and protection; urban storm water management; ground water	Protection from floods and natural disasters in coastal region; management of water catchment area for minimizing	Bangladesh coastal green belt initiative 10 million hectares of Marine Protected Areas, Indonesia (MPAtlas, 2020)

	species, ecological balance of food chains maintained	recharge	climate vulnerability of water resources	
Forest protection and management	Carbon storage, nutrient cycling, water and air purification and maintenance of biodiversity food chains	Drinking water supply; aesthetic value; medicinal plants; sustainable tourism; food supply; livelihoods	Carbon sequestration; ecosystem based adaptation	Landscape approach to conservation and resilience, Bhutan for Life (BfL, 2020) Tropical wetland management, Indonesia (Murdiyarso and Kauffman, 2011)

Source: Dudley (2010); USAID (2017); UNEP-IEMP (2019).

7.3 Trade-offs between action on climate change and biodiversity conservation

Although biodiversity conservation has predominantly been documented for its socio-economic and ecological co-benefits, there are also some examples of the trade-offs between climate actions and biodiversity conservation. Conservation can involve changes in land use which in turn can lock-in adaptation pathways, and as such there will be trade-offs and judgements needed about values and costs (Nalau, 2018). For example, there is a trade-off between trees and crops in agroforestry: Although trees can protect crops from extreme weather events, they can also shade crops and inhibit their growth (Pramova et.al, 2012). Trade-offs and conflicts between the two could also occur due to issues of equity between individuals (Chong, 2014), different value systems (Pramova, et.al, 2012) and adaptation needs where one person's adaptation could be maladaptation for the other (Adger, et.al, 2005).

Recent research has identified the trade-offs between long-term vs. short term benefits of biodiversity conservation. These include trade-offs related to land use (e.g. managing forests for water regulation vs. sustainable harvesting); trade-offs for different community groups (e.g. upstream and downstream communities in forests), and trade-offs for different livelihood groups and current and future generations (Andrade et.al., 2011; Pramova, et.al., 2012; Demuzere,et.al., 2014). Jones et. al. (2012) has noted that while trade-offs are important to recognise, there is still sufficient space to prioritise win-win solutions.

Trade-offs and conflicts between action on climate change and conservation planning is still a nascent area of research with inadequate evidence of the underlying ecological and social complexities. Research gaps exists with respect to quantifying the trade-offs and conflicts and documenting context-specific case studies of trade-offs which may be variable and system dependent (Reside, et.al., 2017). Another area that requires further attention includes approaches for resolving trade-offs through strategic analysis, negotiation and effective communication to better understand the gaps that stand in the way of trade-off decisions (McShane, et.al., 2011).

The literature reviewed identified numerous opportunities for maximising the synergies between action on climate change and biodiversity conservation (Reside et.al., 2017; McShane et.al., 2011; Jones et.al., 2012 etc). Some of these opportunities have been summarised below:

- **Socio-economic and ecological interlinkages in conservation planning and climate action**: Considering that climate change continues to pose uncertain and unaccounted threats to biodiversity and society, there is an important need to document best practices/ case studies on actual measures implemented. Although a lot has already been documented, there is still a need to understand in practice how the complex social, ecological, economic and development interlinkages evolve in the face of climate change.
- **Quantifying cost-benefits and trade-offs:** The monetary and non-monetary benefits as well as the costs and benefits of ecosystems over time and space are still underestimated. Similarly, there is a requirement to quantify the trade-offs between conservation and climate action including the costs of maladaptation.
- **Context specific case studies on synergies and trade-offs:** The benefits and trade-offs of integrating conservation and climate actions are variable and system dependent. Priorities will likely change over a period of time and be influenced by several other variable factors including costs, equity, development needs, choice of intervention and other pressures such as pollution and land use change. It is therefore crucial to document context specific case studies on the different dimensions of these synergies and trade-offs.
- **Monitoring of ecosystem-based adaptation:** Monitoring impacts over long term horizons, measuring socio-ecological complexities as well as monitoring the resilience of ecosystem-based adaptation during the uncertainties of climate change provides immense opportunities for further understanding the synergies and trade-offs.

7.4 Concluding remarks

Despite the wide array of literature available on co-benefits and trade-offs of biodiversity conservation and adaptation approaches, there are still notable research gaps. In particular, the economic valuation of ecosystems poses a challenge related to economic and ecological uncertainty, underestimation of monetary/non-monetary values and lack of integration of complex socio-ecological interdependencies. The economic valuation studies of ecosystems in India and Philippines are steps in the right direction of integrating economic variables into conservation planning and decision making. The monitoring of ecosystems services over long term horizons is also a research gap that needs to be further studied in the region. Another area that requires further attention includes approaches for resolving trade-offs through strategic analysis, negotiation and effective communication to better understand the gaps that stand in the way of trade-off decisions

8 The potential climate and biodiversity benefits of Nature- based Solutions and Ecosystem-based adaptation

Nature-based Solutions (NbS) is an umbrella term that has evolved since the early 2000s from a variety of disciplines which covers a range of actions that protect or restore ecosystems while providing a range of benefits. It rests on the principle that ecosystems are not merely vulnerable to climate change but, if sustainably restored and protected, can contribute to enhancing socio-ecological resilience. Ecosystem-based Adaptation (EbA) is a subset of NbS with a more specific focus on delivering adaptation to climate change (although many of the measures can also deliver climate mitigation benefits, such as deforestation activities).

The concept of NbS is now being used to reframe policy debates on biodiversity conservation, tackling climate change and sustainable development and has informed the investments of multilateral agencies and global institutes. NbS features prominently in Nationally Determined Contributions (NDCs), although often without measurable targets. There is also limited evidence on the effectiveness of different NbS or EbA, mostly because effectiveness depends on the local context and how the approach is implemented. In particular, there are research gaps on the valuation of monetary and non-monetary benefits provided by NbS, due to the methodological and practical challenges in economic valuation. As are result it is not possible to identify the most promising NbS and EbA interventions as this will depend on a detailed study of the local context.

8.1 Definition of Nature-based Solutions (NbS) and Ecosystem-based Adaptation

The concept of Nature based Solutions (NbS) rests on the principle that ecosystems are not merely vulnerable to climate change but, if sustainably restored and protected, can contribute to enhancing socio-ecological resilience. The concept of NbS evolved in the early 2000's from a variety of disciplines including those interested to define the solutions derived from ecosystem services, from the field of biomimicry and industrial design, and from the application of biodiversity in sustainable agriculture (Benyus, 2002; Blesh & Barrett, 2006; Grant, 2012; Kayser & Kunst, 2002; Potschin et al., 2016). Since then, the concept has been extensively studied and refined. This review has used the IUCN's definition of the approach as "*actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits"* (IUCN, n.d.).

NbS has evolved as an umbrella term that builds on and supports other closely related concepts, such as the ecosystem protection-restoration-management approaches, ecosystem services, ecosystem-based adaptation/mitigation, and green infrastructure (IUCN, 2020). The table below summarises the different categories with examples of NbS approaches.

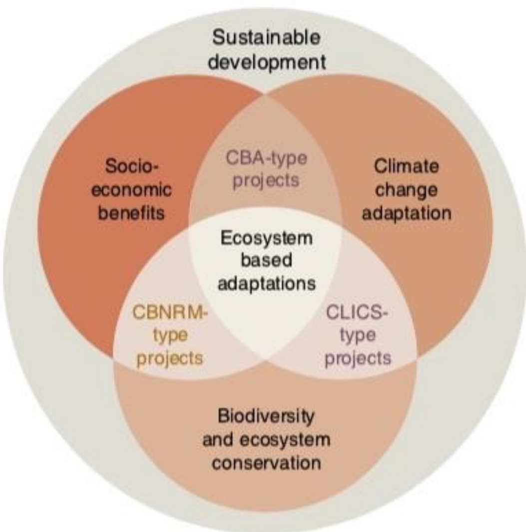
Table 11: Main categories of NbS approaches

Category of NbS approach	Examples
Ecosystem restoration approaches	Ecological restoration Ecological Engineering Forest landscape restoration
Issue specific ecosystem-related approaches	Ecosystem-based adaptation Ecosystem-based mitigation Climate adaptation services Ecosystem-based disaster risk reduction
Infrastructure-related approaches	Natural infrastructure Green infrastructure
Ecosystem-based management approaches	Integrated coastal zone management Integrated water resources management
Ecosystem-protection approaches	Area-based conservation approaches included protected area management

Source: IUCN, 2020.

NbS is therefore a wide concept, and in general signals an orientation towards solutions. Ecosystem-based Adaptation (EbA) can be considered as a subset of NbS with a more specific focus on climate change adaptation. The concept of EbA has been extensively studied with a focus on the ecological, social and economic aspects of ecosystem services in reducing the vulnerability of both people and ecosystems to climate change (Adger, 2005; MEA, 2005; TEEB 2010). It was defined by the CBD as "the use of biodiversity and ecosystem services as part *of an overall adaptation strategy to help people to adapt to the adverse effects of climate change*" (CBD, 2009). The figure below illustrates how EbA draws on different conservation and development approaches including community-based natural resource management, community-based adaptation and climate change integrated conservation strategies (Midgely, 2012; Jiménez Hernández, 2016).

Figure 5: Summary of how EbA draws on different approaches



Source: Midgely, 2012; UNEP-IEMP 2019.

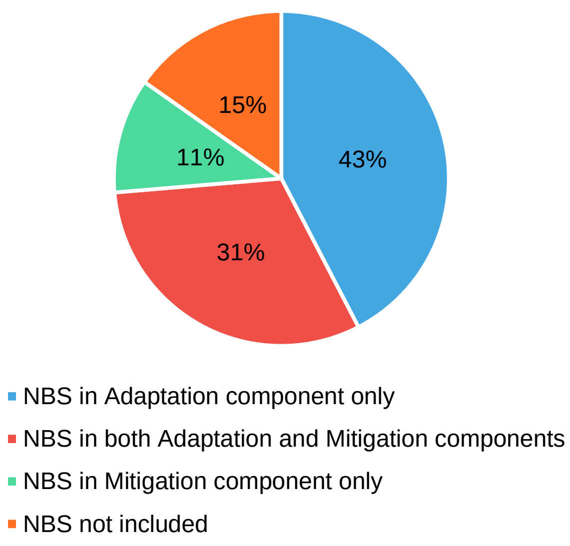
There is a long list of possible EbA actions documented in literature include management and establishment of protected areas, coastal and wetland maintenance and restoration, adaptive forest management and the use of agro-forestry in farming systems. There is also the potential for EbA to deliver mitigation benefits, including through deforestation and degradation (REDD+), enhancement of forest carbon stocks and the role of mangrove, sea grass, and salt marsh ecosystems as important carbon stores. For example, the protected areas of South Asia and South East Asia store up to 52 Gt and 124 Gt of carbon stock per year. This is equivalent to 7.2% and 15% of carbon stock stored in different protected areas around the world (Dudley et.al, 2010).

8.2 Inclusion of NbS and EbA in national climate change strategies and plans

The concept of Nature-based solutions is now being used to reframe policy debates on biodiversity conservation, tackling climate change and sustainable development and has informed the investments of the World Bank, UNEP, the Green Climate Fund (GCF), and Conservation International (Potschin et.all, 2015; MacKinnon et.al., 2008; GCF, 2020; UNEP, 2020, Fedele et.al., 2019).

NbS are also prominent in a large proportion of the Nationally Determined Contributions (NDCs) submitted under the Paris Agreement. including all low-income countries. The figures below illustrates how NbS feature in both adaptation and mitigation components of the 167 NDCs submitted, and the types of ecosystems which were prioritised.

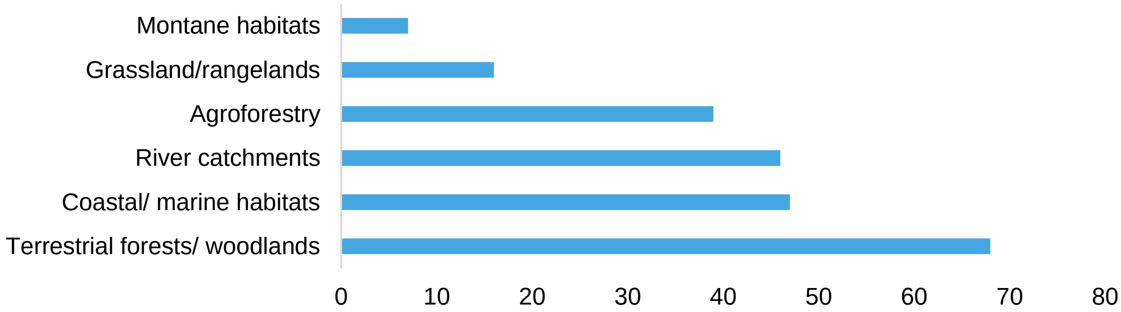
Figure 6: Paris Agreement Signatories that have NbS as part of their NDC.



Source: Nature-based Solutions Policy Platform (2020)

The most commonly implemented or planned NbS adaptation action is the protection, restoration and/or afforestation of terrestrial forests or woodlands, coastal and marine habitats, and river catchments (including wetlands). Far rarer, overall, are plans to restore and protect montane habitats or grasslands and rangelands (NbS Policy Platform).

Figure 7: Number of NDCs prioritising particular types of ecosystems



Source: Adapted from Nature-based Solutions Initiative (2020).

However, documented experience indicates that there is a gap between having commitments on NbS and actual implementation, including translating commitments into robust science-based targets (Seddon et.al., 2019b). On the whole, NDCs rarely include measurable targets or indicators against which progress on climate action through NbS can be tracked. High-level commitments or references to NbS in the NDCs often do not translate into robust evidence-based targets, for example, only 17% of NDCs with current or planned actions involving EbA set quantifiable targets, while only 20% of forest-related targets in the NDCs are quantifiable, and only 8% include targets expressed in tons of carbon dioxide equivalent. Countries rarely include quantified sector-specific targets for agriculture and land-use. Even where measurable targets are set, it is unclear whether they will be sufficient to meet the adaptation needs of the communities and ecosystems involved or achieve the NbS in NDCs (Seddon et al., 2019a).

Table 12: Examples of NbS solutions in NDCs in Asia

Country	NbS vision	Planned NbS actions	NbS targets
Vietnam	Implement ecosystem-based adaptation through the development of ecosystem services and biodiversity conservation, with a focus on the preservation of genetic resources, species at risk of extinction, and important ecosystems	(i) Implement sustainable forest management; (ii) improve the quality of poor natural forests; (iii) implement afforestation and reforestation measures, focusing on large timber plantations; (iv) prevent forest deforestation and degradation; (v) protect, restore, plant and improve the quality of coastal forests, including mangroves, especially in coastal estuaries and the Mekong and Red River deltas.	(i) Forest coverage increased to 45%; and (ii) area of protection forest in coastal areas is increased to 380,000 ha, including 20,000 to 50,000 ha of additional mangrove planting'
Nepal	realizes the importance of reducing climate change impacts and implements climate adaptation actions to protect life and	i) undertake scientific (bio-physical as well as social sciences) approaches to understand and deal with the impacts of climate change in mountains, hills and lowland ecosystems and landscapes;	(i) maintain 40% of the total area of the country under forest cover and forest productivity; (ii) enhance Nepal's forest carbon stock by at least 5% by 2025 compared to

	improve livelihoods of the climate vulnerable communities and also improve ecosystem services	(ii) develop and implement adaptation strategies for climate change affected sectors; and (iii) sustainably manage forest with equal emphasis on enhancing forest carbon sequestration and storage and improving forest governance.	2015 level (iii) decrease mean annual deforestation rate by 0.05% from about 0.44% and 0.18% in the Terai and Siwalik hills respectively; and (iv) put in place a forest carbon trade and payment mechanism by 2025.
Mongolia	Increased adaptive capacity to overcome negative impacts of climate change, and to strengthen resilience of ecosystem and socio-economic sectors'.	(i) To build capacity of community forestry groups to conduct modern technologies for forest seedlings and tree plantations; (ii) to make forests resilient to climate change by improving their productivity and changing their composition and structure; (iii) to train human resources for forest management practices; and (iv) to maintain availability of water resources through protection of runoff formation zones and their native ecosystems in river basins.	Increase forest area to 9% by 2030 through reforestation activities

Source: Seddon et.al. (2019a).

8.3 The potential and effectiveness of NbS and EbA for both climate change and biodiversity conservation

There is literature available documenting the potential benefits of NbS and EbA specifically, which builds on the evidence presented in Section 7 on the possible synergies between biodiversity conservation and climate resilience (Sudmeier- Rieux et al, 2006; Vohland et.al, 2012; Adger, 2000; Hurteau et.al, 2013; Carabine, et.al., 2015). However, the CBD has also highlighted that there are likely to be limitations to using ecosystem-based approaches for adaptation to climate change or disaster risk reduction. Ecosystems too are subject to climate change impacts and therefore vulnerable to climate change (SCBD, 2016).

There are also clear development benefits to these integrated approaches. Economic incentives generally favour expanding economic activity at the expense of environmental conservation or restoration. However, there is clear evidence that biodiversity and ecosystems are essential for progress towards 80 per cent (35 out of 44) of the assessed SDG targets related to poverty, hunger, health, water, cities, climate, oceans and land (SDGs 1, 2, 3, 6, 11, 13, 14, and 15) (IPBES, 2019). For example, in 2007 the ongoing forest conversion in Sulawesi, Indonesia, the pollination services typically provided by the forest was expected to decline continuously and directly reduce coffee yields by up to 18% and net revenues per hectare up to 14% within the following two decades (Priess et.al., 2007). Incorporating the multiple values of ecosystem functions and of nature's contributions into economic incentives has shown better ecological, economic and social outcomes (IPBES, 2019).

In addition, there is evidence demonstrating the climate mitigation benefits of NbS and EbA. A peer-reviewed study led by scientists from 16 institutions (e.g. the Nature Conservancy, Cornell University, World Resource Institute, Wetlands Institute etc) stated that natural climate solutions can deliver 37% of cost-effective carbon dioxide mitigation needed by 2030 for a greater than 66% chance of holding global warming below 2°C this century (Griscom et.al, 2017). This is alongside the existing carbon sink provided by intact ecosystems, which is already absorbing over 25% of human greenhouse gas emissions, and which must be protected from damage by human activities (ibid). Examples include the restoration and conservation of coastal vegetated ecosystems such as mangroves for protection from storm surges, which also enhances carbon sequestration as well as community engagement and livelihood opportunities

These concepts have further been substantiated by demonstrated best practices and case studies documented across the world (see Section 7 for further examples) including: adaptation and mitigation co-benefits of protected areas, economic value of ecosystem services in disaster risk reduction and role of ecosystems in disaster risk reduction (Dudley, et.al. 2010; Sudmeier-Riex, et.al., 2006 etc). See the box below for some specific examples from Asia.

Box 8: Case studies of EbA in Asia

Ecosystems protecting infrastructure and communities, Nepal: The project established demonstration sites for reducing landslide instabilities along road sides using ecosystem-based, locally adapted bioengineering methods. The ecosystem-based approach to disaster risk reduction was shown to be cost-effective and locally adaptable, with great potential for reducing risk while increasing the resilience of communities living in landslide-prone areas. Research studies conducted as a part of the initiative provided guidance for bio-engineering best practices, especially as intense rainfall and longer drought periods are predicted (Devkota, S., et.al. 2014).

Central Asia Climate Risk Management Programme: The multi-country initiative focused on five themes: managing glacial water resources, disaster management, reforestation, livestock management, and water management in agriculture. These efforts were complemented by examples of concrete climate risk management at multiple levels of governance including institutional reforms and legal initiatives. As a result, in Kazakhstan, two districts significantly improved the efficiency of water use in agriculture. Mountainous areas of Kyrgyzstan developed more sustainable pasture management. Tajikistan built capacities for agro-forestry in the Gissar Mountains. Drought management advanced in Uzbekistan through the growing use of drip irrigation (UNDP, 2018).

8.4 The challenge of measuring the benefits of NbS and EbA

There are a number of methodological and practical challenges in measuring and valuing the benefits of NbS and EbA and there is no standard or 'best' approach. They have a number of special characteristics which conventional appraisals and analyses do not necessarily capture, making valuation of their benefits complex. EbA and NbS valuation methods can be clustered into five broad categories, based on their thematic and technical focus (GIZ, 2017). These comprise:

- Biophysical effects – changes in the levels or types of services that are available and used to assist human and natural systems to adapt to climate change.

- Risk exposure and vulnerability – changes in the extent to which people are affected by climate change and are resilient and able to adapt to it.
- Economic costs and benefits – changes in the constraints and opportunities that influence people's ability to produce, consume, trade and invest.
- Livelihood and wellbeing impacts – changes in the constraints and opportunities for people achieve an adequate quality or standard of living.
- Social and institutional outcomes – changes in people's rules, relations, conduct and circumstances.

Despite, the wide array of literature available on co-benefits of biodiversity conservation approaches, there are still some gaps in the valuation of ecosystem services (IPCC, 2014). The monetary and non-monetary benefits (e.g. cultural or research benefits) as well as the costs and benefits of ecosystems over time and space are still underestimated (GIZ, 2017). Economic valuation of ecosystems is difficult due to economic and ecological uncertainty and a lack of integration of complex socio-ecological interdependencies (Sukhdev, et.al 2014). Furthermore, advanced research on the role of ecosystems in disaster risk reduction for different types of natural hazards is also underdeveloped (Sudmeier-Rieux, et.al. 2006). Lastly, challenges associated with long term horizons, complexity of socio-ecological systems as well as ecosystem monitoring for unknown threats and vulnerabilities also limits the data and research on biodiversity conservation (Nalau, 2018). Despite these challenges, economic valuation of NbS and EbA have proven to be useful in demonstrating costs and benefits in certain contexts (see box 9 for an example).

In looking at 13 EbA projects, Reid et. al (2019) discovered that the challenges of fully measuring direct and indirect financial and economic costs and benefits with comparable methods were widely apparent across the projects. While this undermines confidence in the assessment results and means that the playing field is unlikely to be level when comparing EbA with alternative adaptation approaches, it is notable that EbA performed well in most cost-benefit analyses and comparisons with alternatives across the project sites, in spite of the many economic benefits that were excluded from the monetary analyses. So, while cost-benefit analysis can be a useful tool to help decision makers decide whether it makes economic sense to invest in EbA, such approaches alone should not be the basis for investment.

There is a further need for developing robust methods for assessing the direct primary financial costs and benefits and broader economic costs and benefits of EbA (Seddon et al. 2016). Redesigning standard cost-benefit analysis methods to cover a wider set of components of success and effectiveness — including those that are non-monetary and difficult to measure, e.g., food security — would be helpful. There must be more research to develop shared, coherent frameworks that gather monetary and non-monetary values to support better comparison with other adaptation options, thus better informing investment decisions at large scales.

Box 9: Valuation of ecosystems of Manila Bay, Philippines

The economic valuation of net benefits from Manila Bay's ecosystems, mudflats, fish ponds, mangroves and the marine waters, over the next fifty years, has been estimated at $5.4 billion net present value at 6% interest rate. These benefits are generated by three ecosystems - mangroves (69%), brackish and marine waters (20%), and mudflats (10%) that serve both local (60%) and global stakeholders (40%). This valuation includes only a subset of ecosystem services (e.g. importance of migratory birds) or economic losses (e.g. impact of sea level rise) and the computed value therefore underestimates the total economic value. Nevertheless, benefit-cost ratios of restoring the bay outweighs the losses in absence of any restoration measures (UNEP, TEEB, 2020).

In another study, two specific conservation approaches — mangrove protection and planting — were compared with the construction of a 500-meter seawall for coastal adaptation and flood protection in the Philippines. The research team calculated the costs of implementation and estimated that protection of existing mangroves was a cost-effective option. Mangroves, also provided additional benefits including provision of fish, sites for ecotourism and carbon sequestration — estimated to be more than $170,000 annually. The study, however, recognised the merits and limitations of using different methodologist and analytical methods (Baig, et.al., 2016).

8.5 The most promising NbS and EbA interventions in different contexts

There is no universal definition for 'effective' adaptation, much less 'effective' NbS or EbA (Travers.al., 2012). The literature on NbS and EbA indicates that while they offer intrinsic benefits for disaster risk reduction, climate change adaptation and mitigation, as recognised by Sendai Framework for DRR, UNFCCC and CBD their actual effectiveness depends on context and how the approach is implemented. It is therefore very difficult to pick 'winners' from the long list of possible NbS and EbA interventions given it depends on various context factors, including what is the target landscape and geography, timeframe and climate risk (Travers et.al., 2012).

The local context and how the intervention is implemented also determines its level of success, this includes the economic and or social trade-off's, landscape, the "health" of ecosystem, interest and willingness of local communities, the level of technical capacity and financing available, and the regulatory and legal structure, amongst others. There is little documented in literature about effective pathways for implementation (Wamsler and Pauleit, 2016). There is also widespread acknowledgement that there is insufficient quantitative or at least consistently collated qualitative evidence on the comparative effectiveness of NbS and EbA approaches (Reid, 2019).

The table below gives some examples of how varied NbS and EbA interventions can be, and the range of potential different benefits and limitations.

Table 13: Examples of variety of NbS interventions

NbS description	Benefits	Limitations
Mangrove forestation and conservation – provide a natural buffer against coastal erosion and inundation	• Reduction of income wave and tidal energy; • Able to cope with high levels and types of stress; • Habitat creation; • Water quality and regulation; • Potential source of fuel and fiber.	• Not applicable in all areas, generally only in tropics and sub-tropics regions; • Can require a large physical footprint.

Marine Protected Areas (MPAs) - designated areas where varying restrictions apply in order to conserve marine biodiversity and maintain ecological processes and to provide for ecologically-sustainable use, public appreciation, education, understanding and enjoyment of the marine environment	• Increases in the abundance, biomass, diversity and productivity of many organisms • Reductions in the loss of threatened and vulnerable species • Helping ecosystems recover from natural and human impacts • Spillover of fish into areas open to fishing	• Socioeconomic impacts as a result of restricting commercial activity • Requires institutional capacity and on-going monitoring and enforcement
Crop diversification - through the introduction of new cultivated species and improved varieties if aimed at enhancing plant productivity, quality, health and nutritional value and build resilience to pests, diseases and climate change	• Improved drought resilience • Improved yields • Increased resilience to pest and diseases • Increased food security	• Problems can occur with the introduction of exotic species • May require more effort from farmers to manage a broader range of crops
Rainwater harvesting from rooftops - basic technology involves the collection of rainwater from rooftop catchments and diversion to a storage reservoir (tank) for later use	• Improves water security • Reduces the need for wells and bores	• Requires appropriate catchment surface i.e. tin or tiled roof • Not suitable in areas with poor air quality (particulates, dust storms etc)

Adapted from Travers et.al., (2012).

A comparative qualitative study (Reid, 2019) of 13 EbA initiatives in 12 countries highlighted the challenges of measuring effectiveness. It assessed effectiveness in terms whether the projects: Supported local people's capacity to adapt to climate change; Helped ecosystems produce services for local people and allow ecosystems to cope with impacts of climate change and other stresses (e.g., land degradation); and were financially and economically viable. All 13 initiatives were perceived to have improved the resilience of local populations, although a few projects scored less well due to limited direct links to climate change (e.g. unbaked brick production and eco-tourism). The EbA projects also provided many other social benefits, including livelihood opportunities and health improvements, and provided particular benefits vulnerable groups, notably women.

In all 13 initiatives, it was perceived that some stakeholders accrued more adaptation-related benefits than others. These related to changes in land use and therefore changes in the benefits for people depending on the land, for different population groups, for upstream and downstream users, and for people using different parts of a connected ecosystem or under different management regimes. For example, for an incentive-based hilsa conservation project there were some negative socio-economic consequences as a result of the fishing restrictions (see the Box below for further details).

In sum, the research strongly supports the view that "EbA has demonstrated potential to increase social and ecological resilience to climate change and adaptive capacity in the long term" (UNFCCC 2017). It showed that EbA can provide a variety of strong, long-lasting and wide-reaching adaptation-related benefits, social co-benefits and ecosystem-related benefits. The evidence presented on economic effectiveness of EbA is promising and bolsters the view that EbA can in some situations be a more cost-effective approach to adaptation than the alternatives. The research will help policymakers recognise when and how EbA can be effective and enable them to integrate, where appropriate, EbA principles and approaches into national and international climate adaptation policy and planning processes, such as national adaptation plans.

Box 10: Distributional impacts of EbA

An incentive-based hilsa conservation project in Bangladesh demonstrates the complexity in measuring success. The scheme provides compensation to fishers with incentives to abide by fishing restrictions. This improved fish production throughout the river system and beyond. However, there were many unintended socio-economic consequences for certain groups.

Despite compensation in the form of rice, this did not offset the reduced availability of money for other important costs such as buying or repairing nets and boats, which forced many fishers to seek high-interest loans from money lenders during the fishing ban and the high demand for loans brought interest rates up by 20–30%. In addition, when rice was distributed during the fishing ban, rice retailers and wholesalers sold less, so compensating fishers in this way put other sections of the community at an economic disadvantage. In addition, during the fishing ban, many fishers and supply-chain workers sought casual work elsewhere, flooding the local labour market and driving down local labour wages by up to 40%.

Reid et.al. (2019)

8.6 Concluding remarks

The field of research on NbS is growing and it is quickly entering the policy lexicon. However, much of the research on NbS and EbA remains conceptual, and documented results and learning from practice is limited. The concepts remain broad, and the range of types of measures that could be categorized as a NbS is very large. A focus moving forward for the research community is to further define and assess the approaches being implemented in practice by a wide range of organisations (UNEP, IUCN, CI, TNC, WWF, CARE etc) (Carabine, et.al. 2015). This will help to refine and categorize the types of measures and interventions that fall within the NbS and EbA concept.

There is also limited evidence on the potential effectiveness of EbA across different types of ecosystems, in particular for grasslands/ savannahs, mountain and marine biomes (ibid). Because EbA remains a loosely defined approach without definite quantitative measures, many relevant interventions are not labelled as EbA (Doswald, et.al. 2014). It is therefore difficult to compare the effectiveness across types of interventions and locations.

Nevertheless, as shown by Reid et. al (2019), EbA's can be individually assessed for their efficacy in terms of: effectiveness for human societies – did the initiative allow communities to improve or maintain their adaptive capacity or resilience while enhancing co-benefits that improve their well-being?; ecosystem effectiveness – did the initiative restore, maintain or enhance the capacity of ecosystems and its services for local communities, and its ability to withstand climate change impacts and other pressures?; financial effectiveness – is it cost-effective and financially viable over the long-term?; and policy and institutional dimensions – what social, institutional and political issues influenced the implementation of effective EbA initiatives and how might challenges best be overcome?

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Annex A Planned climate actions from selected countries (South, Southeast, & Central Asia)

Climate actions	Pakistan (Chaudhry & Sohail, 2013; Khan, 2008; Parry, 2016)	Vietnam (Nhat, 2017; UNDP, 2018)	Tajikistan (Daze, 2016)
Water resource management	• Adoption of water conservation measures • Development and implementation of integrated water resource management • Development of legislation to protect water resources • Enhance capacity to manage hydrological systems • Develop resilient water infrastructure	• Formulate and integrate sustainable water development planning • Reinforce, upgrade, and complete existing water resource infrastructure, and add new infrastructure • Upgrade and modernize hydro-meteorological observation, long range and seasonal forecasting	• Improve hydrological observation, monitoring, and forecasting systems • Adopt water conservation and efficiency measures • Implement measures to protect against floods, mudflows, and landslides • Construct reservoirs • Monitor glacial melt
Agriculture	• Build climate resilience into agricultural system • Enhance crop productivity through improved irrigation and land management • Enhance institutional capacity to undertake research on agriculture and livestock • Enhance understanding of climate change issues by agricultural stakeholders	• Ensuring food security and generating livelihood opportunities • Streamlining and duplicating models of integrated farming, climate smart agriculture, and agroforestry • Prevent soil erosion, implement soil protection • Shift to climate resistant crops and cropping patterns • Redistribute regional crop and	• Shift to drought and pest resistant and salinity tolerant crop varieties • Introduce practices to reduce erosion and salinization • Implement small scale irrigation for crop and pasture lands • Introduce community based agro forestry • Increase access to climate information for actors in the agricultural sector

		livestock production to better suit changing climatic conditions	
Forestry	• Improve understanding of relationship between forests and climate • Minimize damage and increase resilience of forest ecosystems • Improve governance and management of forests to cope with climate change • Build institutional capacity on climate change adaptation	• Streamlining and duplicating models of agroforestry	• Introduce community based agro forestry • Rehabilitate forests in drought and wind erosion prone areas
Health	• Address climate change impacts on human health	• Build capacity and strengthen infrastructure network to respond to climate change related health risks	• Increase public awareness of climate change impacts on health • Introduce hydrotechnical, physical, and biological methods to protect against mosquitoes • Improve access to safe sources of water • Improve nutrition
Biodiversity & ecosystem protection	• Strengthen legal and institutional set-up for biodiversity conservation • Map out ecosystem vulnerability for mountains, wetlands, arid regions, coastal regions and prepare mitigation action plans • Develop adaptation strategies for key ecosystems (coastal, mountains, wetlands, rangelands)	• Restoring and increasing forest and mangrove covers • Strengthen and elevate embankments in coastal regions	
Urban planning	• Introduce innovations in town	• Designing technical standards and	

& development	planning to adapt and mitigate climate change impacts	regulations for climate proof urban infrastructure • Improving urban planning based on climate change and sea level rise scenarios	
Energy			• Construct or modify hydropower plants to address changes in river flows • Protect facilities and downstream communities from floods and mudflows by adjusting dams and channels • Improve hydropower plant management to anticipate and respond to climate risks
Climate information	• Enhance understanding of climate change issues by agricultural stakeholders	• Developing a system for assessing and monitoring climate change and sea level rise	• Increase access to climate information for actors in the agricultural sector • Improve hydrometeorological monitoring system • Strengthen forecasting and early warning systems • Strengthen emergency response systems
Food security	• Protect food security of mountain regions	• Ensuring food security	
Disaster risk management	• Improve understanding of natural hazards • Develop integrated hazard	• Creating flood risk maps and improving early warning systems • Improve natural disaster	• Strengthen emergency response systems • Strengthen forecasting and early

	mitigation strategies • Assess likely future flood levels • Provide reliable early warning for natural disasters • Develop disaster resilient infrastructure	forecasting	warning systems • Continue institutional strengthening for hydrometeorological services
Infrastructure	• Develop climate change resilient water infrastructure • Develop disaster resilient infrastructure	• Reinforce, upgrade, and complete existing water resource infrastructure, and add new infrastructure • Designing technical standards and regulations for climate proof urban infrastructure	• Protect power lines and other infrastructure from floods and mudflows
Institutional strengthening	• Enhance capacity to manage hydrological systems • Enhance institutional capacity to undertake research on agriculture and livestock • Build capacity of forestry institutions on climate change adaptation		• Continue institutional strengthening for hydrometeorological services

Annex B: Country-specific estimates of economic impact from select studies

Country	Change in per capita GDP growth (in % points) 2010-2099	Impact on per capita GDP growth (in % points)			Long term change in annual GDP (% change per year)
		RCP 2.6	RCP 8.5	Benefit from adopting RCP2.6 (in % points)	
Bangladesh	-57	-2.15	-8.59	6.44	-7.59
Bhutan	-5	-10.33	-17.76	7.43	
Cambodia	-53	-1.84	-0.74	-1.1	-12.1
Fiji	-22	-2.39	-7.12	4.73	
India	-35	-2.57	-9.9	7.33	-10.35
Indonesia	-33	-1.92	-7.51	5.59	-13.27
Kyrgyzstan	63	-1.86	-10.85	8.99	-0.93
Lao People's Democratic Republic	-40	-0.78	-2.34	1.56	-10.62
Myanmar		-0.25	-2.24	1.99	
Nepal	-76	-5.34	-13.15	7.81	-5.73
Pakistan	-36	-0.88	-9.55	8.67	-6.44
Papua New Guinea	-43	-1.44	-6.99	5.55	

Philippines	-25	-3.05	-8.46	5.41	-14.79
Samoa	-19	-3.64	-8.31	4.67	
Solomon Islands	-38	-1.04	-5.98	4.94	
Tajikistan	-7	-0.38	-9.35	8.97	
Thailand	-19	-0.06	-3.98	3.92	-9.24
Uzbekistan	-13	-3.11	-11.72	8.61	
Viet Nam	-31	-0.02	-5.15	5.13	-7.95
Source	*Burke, Hsiang & Miguel, 2015*	*Kahn et al., 2019*			*Kompas et al., 2018*
Climate scenario	RCP 8.5				3°C increase in global temperature

Annex C: Examples of resilience indicators

(Bizikova et al., 2019) Identifies a range of indicators under the headings: (1) climate change – seasonality and severe weather events; (2) Demographics (e.g., (3) Farm production activities; (4) local market economy characteristics (5) Rural infrastructure and (6) Environmental services.

(1) climate change – seasonality and severe weather events;

Changes in growing season	Agriculture – Seeding date (more then 15 days difference compared to provincial average for the last 5 years)
Late spring frost (date)	Date of the spring frost within the average frost days between May 1 and June 20;
Extreme heat	Three or more days > 32 °C threshold will be used; calculated per month
Heat spell duration	Max number of consecutive days with daily max temperature threshold of 5 °C above normal, by month
Wet spell duration	Consecutive wet days by season; threshold of above 1 mm will be used
Drought frequency	Changes in annual length, by month thresholds by crops and compared to available moisture is 20% less than crop water requirement. This is based on provincial policy threshold
Drought severity	Provincial policy defines current thresholds for drought severity. Threshold is changing in terms of timing or seasonality (it is becoming an issue in other seasons)
Deficit/Excess water	Streamflow/discharge rates; the threshold is based on flood forecasting and warning with thresholds compared to last 10 years of water deficit/excess

(2) Demographics

Agricultural producers as proportion of total rural population	Percentage and change compared to the provincial average for the last 10 year
Rural inhabitants as proportion of total regional population	Percentage and threshold compared to provincial average
Age of farmers	Average and compared to the threshold defined by the national retirement age
Share of rural population more vulnerable to climate change	Percentage of rural population seniors/children, socioeconomic status, health status compared to provincial average for the last 5 years

(3) Farm production activities;

Yearly agricultural output compared with long-term average	Per ha or kg compared to the provincial average for the last 5 years
Mix of crop type, perennial vs. annual	Proportion or total hectares compared to the provincial average for the last 5 years
Livestock density	Animals/ha by type compared to the provincial average for the last 5 years
Portion of farm infrastructure in floodplains	Percentage compared to the provincial average for the last 10 year
Portion of barns with air conditioning	Percentage compared to the provincial average for the last 10 years

Portion of land with tile drainage	Percentage compared to the provincial average for the last 10 years
Proportion or hectares of farmland under conservation, no-till, rotational grazing	Percentage or hectares of total land under production compared to the provincial average for the last 10 years
Manure management strategies	Prevalence by type based on the thresholds listed in provincial policies

(4) local market economy characteristics

Percentage of farms with off-farm income	Percentage compared to the provincial average for the last 5 years
Medium and average farm size with insurance coverage	Percentage compared to the provincial average for the last 5 years
Level of debt per farm type	Average, median compared to provincial average and change over the last 5 years average
Gross domestic product in rural area	Monetary value of all finished goods and services for bounded region compared to the provincial average for the last 5 years
Relative shares of small, medium and large farms	Percentage of small and medium farms from the total number of farms compared to the provincial average for the last 10 years

(5) Rural infrastructure

Road density in the flood plain	Percentage and length of roads located at the floodplain compared to provincial average
Age and condition of the infrastructure	Roads, bridges, communications compared to the provincial average for the last 10 years
Portion of population with small/ private drinking systems	Percentage not using municipal drinking water systems compared to the provincial average for the last 10 years
Frequency of drinking water shortages or contamination	Number of events per year compared to the provincial average for the last 10 years
Access, location, density of health emergency systems	Number and percentage of communities with below average rural provincial access to services compared to the provincial average for the last 5 years

(6) Environmental services

Watershed buffer zone	Percentage shoreline permanently vegetated: 30 m high water; 120 m for certain wetlands based on the provincial policy
Undisturbed land cover	Percentage or total hectares forest or wetland compared to the provincial average for the last 10 years
Reforestation, deforestation	Percentage of land cover or total hectares change over the last 5 and/or 10 years average
Rural land management and species biodiversity	Land fragmentation index and compared to the provincial average for the last 5 and or 10 years
Erosion risk	Risk of soil erosion due to wind and water as percentage of total (agricultural or other) land compared to the provincial average for the last 10 years
Species range shifts (e.g., hantavirus, invasive)	Incidence of reported pests and disease with focus on emerging pests.

(USAID, 2018) sets out indicators for absorptive capacity, adaptive capacity and transformative capacity:

Farm Level					
	Financial Capital	**Human Capital**	**Natural Capital**	**Physical Capital**	**Social Capital**
Absorptive capacity	Net income/ poverty level	Food security and nutrition	On-farm soil health	Access to early-warning systems	Access to informal safety nets
	Savings sufficient for emergencies	Labor for focus crop	On-farm water health	Weather-proof post-harvest infrastructure	
	Insurance	Access to technical assistance	On-farm biodiversity	Weather-proof transportation infrastructure	
Adaptive Capacity	Income diversification	Use of climate smart Practices	Access to climate-ready varieties of focus crop	Access to climate change projections	Access to knowledge sharing groups re: climate change
	Financial Capital	**Human Capital**	**Natural Capital**	**Physical Capital**	**Social Capital**
	Access to credit		Altitude for altitude sensitive crops	Access to clean & appropriate technologies	Participation in local decision-making
Transformative Capacity	Savings sufficient for investment	Innovation Potential	Access to quality planting material for alternative, climate ready crops	Access to alternative, climate-ready value chains	Quality of enabling environment
					Participation in decision-making structures affecting farming community
Intermediary Aggregator Level					
Absorptive Capacity	Profitability	Management experience in target crop	Access to water	Energy reliability	
	Financial stability	Management capacity		Weather-proof facilities	
	Liquidity	Employee loyalty		Weather-proof transportation infrastructure	
	Insurance	Supplier loyalty			
Adaptive Capacity		Supplier engagement for cooperatives			
		Succession plan	Access to renewable energy		
		Investment in employee development	Access to climate ready varieties of focus crop		
		Investment in extension			
Transformative capacity	Access to buyers for alternative, climate ready crop	Innovation potential (likelihood of innovating)	Access to planting material for alternative, climate ready crop	Access to alternative, climate-ready value chains	Access to industry network re: alternative, climate ready crop
	Access to start-up capital	Management experience in alternative crops			"Stickiness" of current suppliers (willingness to follow business into new crop)
		Access to suppliers of alternative, climate ready crop			

(Summers et al., 2017) includes suggested indicators for the natural environment (extent and integrity); Society (economy, services, characteristics); Built environment (infrastructure); governance (preparedness and response); and risk (losses and exposure).

Sub-indices	Domains	Indicators
Natural Environment	Extent	Managed Lands
		Ecosystem Type
	Integrity	Condition
Society	Economy	Economic Diversity
		Employment
		Insurance
	Services	Safety and Security
		Social
		Labor/Trade
	Characteristics	Demographics
		Health
Built Environment	Infrastructure	Communication
		Transportation
		Utilities
	Structures	Non-Residential
		Residential
		Shelter
Governance	Preparedness	Planning
		Investment
	Response	Expenditure
		Time
Risk	Losses	Property
		Human
	Exposure	Geophysical
		Technological Hazards

(Jacobi et al., 2018) formulates dimensions of resilience and the following indicators:

Resilience Dimensions	Indicators
Buffer capacity	Diversity of crops and breeds
	Natural capital
	Human capital
	Financial capital
	Social capital
	Physical capital
Self-organization	Decentralization and independence
	Local consumption of production
	Interest groups
	Ecologically self-regulated
	Appropriately connected
Capacity for learning and adaptation	Knowledge of threats and opportunities
	Reflective and shared learning
	Functioning feedback mechanisms
	Existence and use of local traditional knowledge
	Shared vision