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Climate action for food security in South Asia? Analyzing the role of agriculture in nationally determined contributions to the Paris agreement

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ABSTRACT

The Nationally Determined Contributions (NDCs) submitted under the Paris Agreement propose a country's contribution to global mitigation efforts and domestic adaptation initiatives. This paper provides a systematic analysis of NDCs submitted by South Asian nations, in order to assess how far their commitments might deliver meaningful contributions to the global 2°C target and to sustainable broad-based adaptation benefits. Though agriculture-related emissions are prominent in emission profiles of South Asian countries, their emission reduction commitments are less likely to include agriculture, partly because of a concern over food security. We find that income-enhancing mitigation technologies that do not jeopardize food security may significantly augment the region's mitigation potential. In the case of adaptation, analysis shows that the greatest effort will be directed towards protecting the cornerstones of the 'green revolution' for ensuring food security. Development of efficient and climate-resilient agricultural value chains and integrated farming bodies will be important to ensuring adaptation investment. Potentially useful models of landscape level climate resilience actions and ecosystem-based adaptation are also presented, along with estimates of the aggregate costs of agricultural adaptation. Countries in the region propose different mixes of domestic and foreign, and public and private, adaptation finance to meet the substantial gaps.

Key policy insights

- Though substantial potential for mitigation of agricultural emissions exists in South Asia, governments in the region do not commit to agricultural emissions reductions in their NDCs.
- Large-scale adoption of income-enhancing technologies is the key to realizing agricultural mitigation potential in South Asia, whilst maintaining food security.
- Increasing resilience and profitability through structural changes, value chain interventions, and landscape-level actions may provide strong options to build adaptive capacity and enhance food security.
- Both private finance (autonomous adaptation) and international financial transfers will be required to close the substantial adaptation finance gap

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Introduction

Nationally Determined Contributions (NDCs) – defining country commitments towards long-term global emission mitigation goals and domestic adaptation actions in accordance with national priorities – form the core of

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the 2015 Paris Agreement (UNFCCC, 2015a). Currently available assessments, however, show that NDCs fall short of the least cost path to the global goal of limiting warming to 2°C by 8.7 Gt CO_2eq by 2025 and 15.2 Gt CO_2eq by 2030 (UNFCCC, 2015b). According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), global cumulative CO_2 emissions after 2011 have to be confined to less than 1000 Gt CO_2 for a 66% chance of limiting the temperature rise below 2°C. The remaining emission budget will be 467 Gt CO_2 in 2025 and 261 Gt in 2030 (UNFCCC, 2015a). Thus, future ratcheting-up of the NDCs, which will be updated in 2020, must include substantial additional mitigation actions to meet the 2°C target, supplemented by appropriate adaptation actions.

Globally, agriculture is a major greenhouse gas emitting sector, accounting for 5.2–5.8 Gt CO_2eq of emissions directly, or around 11% of the global aggregate. This is compounded by a similar level of indirect emissions due to agriculture's dominant role in deforestation and land use change (Smith et al., 2014). This fact is reflected in NDCs, with agriculture considered in the mitigation contribution of 78% of the submissions (FAO, 2016). At the same time, agriculture as a sector is especially vulnerable to climate change, particularly for the large number of small-scale farmers in developing countries who are dependent on rainfed croplands and pastures for their livelihoods and food security (Campbell et al., 2016). This situation is reflected in the fact that 95% of developing country NDCs include specific agricultural measures and policies for adaptation (FAO, 2016). Article 2.1(b) of the Paris Agreement recognizes the dual role of agriculture, stressing the need of 'increasing the ability to adapt to the adverse impacts of climate change and foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production'. The stated inter-connected challenges of climate change and agriculture, and linkages with food security, are particularly pronounced in South Asia (Bandara & Cai, 2014). For the purposes of this paper, South Asia is considered to include Afghanistan, Bangladesh, Bhutan, India, Myanmar, Nepal, Pakistan and Sri Lanka. Agriculture accounts for 23–67% of the region's total emissions (PRIMAP, 2016), far higher than the global average. At the same time, 600 million South Asians live under the World Bank poverty line of less than US$1.25 a day, the majority of whom depend directly or indirectly on agriculture (Hertel, Burke, & Lobell, 2010).

Transitioning to agricultural development that provides climate change solutions and maintains food security is clearly a priority across South Asia. The NDCs provide an opportunity to understand how seriously governments are taking up the twinned challenges of mitigation and adaptation in their agriculture sectors. The purpose of this research is to provide a systematic analysis of NDCs submitted by South Asian nations, in the context of their adaptation plans, national agricultural policy documents and climate expenditure reviews, to assess how far their commitments might deliver meaningful contributions to the global 2°C target and to sustainable broad-based adaptation benefits, including food security.

Agriculture-based mitigation commitments in the NDCs of South Asian countries

Large-scale agriculture-based mitigation actions are not prominent in the NDCs of South Asian countries. Given their higher share of agricultural emissions to aggregate emissions (Table 1), India, Pakistan and Bangladesh could potentially undertake mitigation actions in this sector that could significantly contribute to global mitigation targets. Yet it is only Bangladesh, along with smaller emitters such as Afghanistan, Myanmar, Nepal and Sri Lanka, that specify in their NDCs that they will take mitigation actions in agriculture (Table 1). These countries specify types of actions, including quantitative targets. For example, Bangladesh aims at a 50% reduction in the number of draft animals to reduce livestock-related emissions, and a 35% increase in organic fertilizer to reduce the nitrous oxide emissions associated with the use of chemical fertilizers. Bangladesh also intends to use alternate wetting and drying (AWD) irrigation technology, which reduces methane emissions, in 20% of the rice paddy area. Afghanistan, Myanmar, Nepal and Sri Lanka similarly propose actions in croplands and manure management.

India, with the largest agricultural emissions in the region, is notable in its limited reference to agricultural mitigation actions in its NDC, which focuses on clean energy and industry. However, a number of actions in India's NDC are implicitly related to mitigation effort in agriculture. The major portion of agricultural CO_2 emissions from India is from electricity used for groundwater pumping (Amjath-Babu & Kaechele, 2015). Therefore, an overall switch to cleaner energy sources will reduce carbon emissions from the agricultural sector, even though it is not explicitly mentioned as an agricultural action in the NDC. Use of solar electric pumps as a

Table 1. Agricultural emission mitigation in NDCs of South Asia.

	Afghanistan	Bangladesh	Bhutan	India	Myanmar	Nepal	Pakistan	Sri Lanka
Share of global emissions (without LULUCF) in 2010 (PRIMAP, 2016)	0.1%	0.3%	0.0%	6.8%	0.2%	0.1%	0.9%	0.1%
Projected share of global emissions (without LULUCF) in 2030 (PRIMAP, 2016)	0.1%	0.5%	0.0%	8.9%	0.2%	0.1%	0.9%	0.1%
Total national emissions per annum (Mt CO2-eq) including LULUCF in 2010 (PRIMAP, 2016)	40	160	4	2952	8	42	399	26
Emissions from LULUCF in 2010	9	19	2	−208	−97	8	6	−6
Direct emissions from agriculture excluding LULUCF as a percentage of total emissions in 2010 (PRIMAP, 2016)	52%	38%	28%	25%	70%	69%	38%	28%
Mitigation target in NDC	0–14% reduction on BAU of 48.9 Mt	5–15% reduction on BAU of 234 Mt	No quantitative target	Reduction of emissions intensity of GDP by 33–35% from 2005 levels by 2030	No quantitative target	No quantitative target	0% reduction on BAU of 511.8 Mt	7–23% reduction on BAU of 29.3 Mt
Does the NDC include reductions in LULUCF emissions in its mitigation target? Yes/No			Yes – Conserving the current forest land share at 70.46%	Yes – Carbon sequestration of 2.5–3 billion tonnes by 2030		Yes – increase forest carbon stock by at least 5% by 2025 as compared to 2015 level		
Does the NDC include reductions in direct emissions from agriculture in its mitigation action portfolio? With a quantitative target?	Yes Yes	Yes No	No No	No No	Yes No	Yes No	No No	Yes No

(*Continued*)

Table 1. Continued.

	Afghanistan	Bangladesh	Bhutan	India	Myanmar	Nepal	Pakistan	Sri Lanka
Key mitigation measures related to agriculture	Reduced fertilizer application, optimal timing of fertilizer applications and use of nitrification inhibitors	50% reduction in draft animals, 35% increase in organic fertilizer and reducing methane emissions by using alternate wetting and drying technique in 20% paddy rice area			Adoption of alternate wetting and drying irrigation technology, reducing crop residue burning in fields, bioenergy production from crop residues, use or organic fertilizers, addition of biochar	Organic farming and reduce the use of agro-chemicals		Reduce the use of chemical fertilizers and promote manure management

Source: NDC (Afghanistan), NDC (Bangladesh), NDC (Bhutan), NDC (India), NDC (Myanmar), NDC (Nepal), NDC (Sri Lanka). PRIMAP, 2016, Factsheets: Intended Nationally Determined Contributions (INDCs), https://www.pik-potsdam.de/primap-live/indc-factsheets/.

mitigation action is mentioned in the NDC and is expected as a major initiative. Agriculture is also a part of the mitigation programme through an aspirational target of 20% blending of biofuels with fossil fuels.

Notably, South Asian nations do not give quantitative targets for sector-wide emissions reductions in agriculture (Table 1). Only Afghanistan explicitly includes agriculture in its overall numerical mitigation commitment towards the Paris Agreement.

Beyond agriculture, a number of South Asian nations include large-scale carbon sequestration activities through forestry. The potential is high; for example, Bhutan currently has negative carbon emissions because its forests sequester 6.3 million tonnes of CO_2, well above its 2013 emissions level of 2.2 million tonnes (Munawar, 2016). India aims at the sequestration of 100 million tonnes CO_2eq annually through afforestation of 5 million hectares (By comparison, China intends afforestation of 40 million hectares by 2020). Given the large area under wastelands in India (64 million hectares), land does not seem to be a constraint for afforestation. Nevertheless, many classes of wasteland, such as steep slopes, glacial zones or shifting cultivation areas, may not be suitable for afforestation actions and hence only 27 million hectares may actually be available, constrained further by slow acquisition of land from multiple owners (Maji, Reddy, & Sarkar, 2010). Similar land constraints are applicable to large-scale solar energy production as well.

While there is significant mitigation potential in South Asian agriculture and land use, governments are not yet enthusiastic about deploying or scaling-up technologies, practices or institutions. Given South Asian governments' focus on food security, any possible trade-offs of listed emission mitigation technologies with agricultural production can be a strong deterrent in bringing these actions to significant scale. Cereal demand in South Asia is expected to increase 1.6% annually (ADB, 2013) due to population growth and consumption changes, which need to be met by intensifying production (FAO, 2012). Fertilizer use intensity is 121 kg ha^{-1} in South Asia and it is expected to increase to 268 kg ha^{-1} by 2050. By comparison, China's NDC states an aim to achieve zero growth of fertilizer use by 2020. But the current fertilizer use intensity is 364 kg ha^{-1} in China, which is almost triple the South Asian average and more than double the Indian average (World Bank, 2016). So the South Asian goal of stabilization and even reduction of fertilizer, as commonly stated in their NDCs, can only be achieved by major gains in nutrient use efficiency plus large-scale efforts to recycle agricultural, animal and urban bio-wastes back to farms. Regarding reduction of methane emission from paddies, though AWD is a proven methodology, the labour intensity of its practice, weak incentives for water use reduction, infrastructural needs for water control and lower gain in yield levels (and the risk of yield loss especially if the threshold of soil drying is breached (see Carrijo, Lundy, & Linquist, 2017)) may make its wider adoption difficult (Carrijo et al., 2017; Ly et al., 2012). Nevertheless, it is expected that South Asia's irrigated rice area may decline from 31 to 24 million ha by 2050 (replaced by maize) and hence a reduction in water withdrawal from 913 to 896 km^3 is expected (FAO, 2012). This could potentially reduce CO_2 emissions from energy use for water pumping and methane production from paddies.

Possibilities to augment the role of agriculture in the mitigation component of NDCs include co-location of agriculture with solar energy projects and co-production of third generation biofuels in agricultural fields; for example, growing algae in paddy fields can potentially inhibit methane emissions (Chanakya, Mahapatra, Sarada, & Abitha, 2013) and generate stock for biofuel without reducing rice production. Nevertheless, technologies for agricultural production in solar farms (Ravi et al., 2016) and converting algal biomass to biofuel, are at the pilot stage. Technology transfer may have a crucial role in promoting such mitigation options. This fact highlights the importance of platforms such as the Global Research Alliance (https://globalresearchalliance.org), which promotes research, development and extension of technologies and practices that can increase agricultural production and climate resilience while reducing greenhouse gas emissions. Currently, Sri Lanka is the only South Asian country that has joined the alliance.

Emissions reductions in agriculture are not generally economically rewarded in South Asia; no direct incentive mechanisms like tradable carbon credits or carbon payments at farm level exist to date. Thus, large-scale adoption of improved practices must be economically justified based on co-benefits such as saved water, reduced costs or increased production. Hence developing technologies that can give significant income enhancement for farmers while reducing emissions are of primary importance. Such practices and technologies may trigger large-scale autonomous adoption (Hertel & Lobell, 2014) under ideal economic and institutional conditions. Currently, bioenergy is not on the rise in South Asia, in part due to concerns over competition

with food production. In India, biofuel crops are currently intended to be cultivated in marginal or waste lands only. Third generation biofuels (eg: co-production of algae with paddy) and solar energy co-production (co-location of agriculture with large-scale solar facilities) could be examples of *prima facie* economically attractive technologies that could potentially be expanded without competition with food production, but their technical and economic viability has to be further tested.

Agricultural adaptation in the NDCs of South Asian countries

All South Asian countries list agriculture as a priority sector for adaptation in their NDCs. This is as expected, since ensuring food and livelihood security of millions of farmers in the region is a prime goal. The NDCs reveal a dichotomy in attitudes to agricultural adaptation and mitigation, common across all countries in the region. Agriculture is understood primarily as vulnerable to climate change and hence adaptation is taken as the major goal in agriculture. Despite the sizeable share of agricultural emissions in the regional emission profiles, mitigation is by contrast a low priority. The NDCs have been developed through bottom-up processes, showing that these views are widespread among civil society as well as governments and technical advisors.

Key actions on adaptation in agriculture are shown in Table 2. Proposed adaptation actions broadly include early warning systems and disaster risk reduction, water management, crop and livestock husbandry, and soil management. We analyzed national agricultural policy documents, adaptation plans and climate change-related expenditure reviews to understand whether the adaptation actions listed in NDCs are indeed given priority in their respective countries. For example, in India, the major domestic strategies are the national mission on sustainable agriculture, the national initiative on climate-resilient agriculture and the national agroforestry policy.

In the case of agricultural water management, there is a general aim to expand irrigated areas, increase efficiency of irrigation, scale up micro-irrigation technologies and enhance water harvesting. Bhutan, Myanmar and India state their intention to utilize integrated water management as a framework while Bhutan is the only country that prioritizes climate-proofing of water resources, which could be due to higher probability of glacial lake outburst flood events. Many countries in the region would like to enhance meteorological and hydrological monitoring, especially application of satellite-based technologies. These listed actions require major investment to be effective in reducing the impact of increased variability in rainfall (Aggarwal, Joshi, Ingram, & Gupta, 2004). The current trends show that South Asian countries indeed invest considerable resources in the listed actions (Table 2) with possible trade-offs with global mitigation goals. For example, expansion of irrigation can potentially increase greenhouse gas emissions due to added energy use in groundwater pumping (Rothausen & Conway, 2011) or added methane emissions from irrigated paddies. Hence the water-food-energy-emission nexus approach needs to be an inherent feature in agricultural adaptation in South Asia to minimize the trade-offs (Rasul & Sharma, 2016).

Regarding husbandry, every country in the region would like to increase use of stress-tolerant crop varieties and livestock breeds. India and Bangladesh already devote considerable resources to their development. Though a shift towards less water-intensive crops like maize might be expected, no country other than Sri Lanka considers changing or diversifying crop species as an adaptation option in their NDC. Most of the South Asian countries would like to reduce chemical fertilizer use and increase the use of organic fertilizers. This is expected to provide soil fertility (Aggarwal et al., 2004), water conservation and soil carbon sequestration benefits while reducing emissions from fertilizer production (CO_2) and application (N_2O), but may conflict with goals to increase total crop production. The NDCs of Bhutan and Sri Lanka specifically refer to 'climate-smart agriculture' (Chandra, McNamara, & Dargusch, 2018; Lipper et al., 2014), which aims at increasing productivity, food security and climate resilience while decreasing emissions. Bhutan envisages conservation agriculture and other sustainable farming options towards attaining such a goal. India and Bhutan list crop insurance as a means to increase economic resilience of farming systems; India has already made significant advances in providing crop insurance to small-scale farmers (Mukherjee and & Pal, 2017). Though Pakistan's NDC does not elaborate adaptation actions, the fact that 45% of federal expenditure on adaptation is related to water resources shows its thematic dominance among adaptation actions (UNDP, 2015).

In addition to farm-level adaptation options, several South Asian countries list measures at the landscape level (Table 2). Nepal, Bangladesh, Sri Lanka and Bhutan propose 'ecosystem-based adaptation'

Table 2. Key agricultural adaptation measures (excluding disaster management) listed in NDCs of South Asia.

Key adaptation measures	Afghanistan	Bangladesh	Bhutan	India	Myanmar	Nepal	Sri Lanka
Agricultural Water management							
Irrigation infrastructure rehabilitation, expansion and investment	✓ listed as priority area		✓ listed as priority area (20% of government's climate related expenditure)	✓ One of the goals of National Water Mission ($6.14 billion)		✓ listed as priority area in Agriculture Development Strategy (14–22% of government's climate related expenditure is for irrigation)	√
Integrated water management, Watershed management, Water harvesting, Climate proofing of water distribution	√		✓ accounts for 1.3% of total government expenditure	✓ Neeranchal project ($357 million)	√	√	✓ listed as priority area stressed in adaptation plan
Groundwater management, Waste water reuse				√			√
Efficient irrigation systems (Sringler, drip etc.)				✓ PMKSY scheme or Prime Minister's agricultural irrigation scheme (0.7 billion 2015–16)			✓ listed as priority area stressed in adaptation plan
Meteorological/ ecological/ hydrological monitoring networks / satellite based monitoring	✓ listed as priority area		✓ listed as priority area	√			
Crop Management							
Stress-tolerant varieties and livestock breeds	√	✓ listed as priority area	✓ listed as priority area	√	✓ listed as priority area	√	✓ listed as priority area
Switch in crop types							√
Organic farming			√	✓ Traditional farming improvement programme ($45 million in 2015–16)		√	
Reducing agro-chemicals and increasing organic amendments	√	√		√		√	√
Crop insurance			√	✓ $250 million per year for Prime Minister's Crop Insurance programme			
Climate-smart or climate-resilient agriculture			√	✓ National Initiative on Climate Resilient Agriculture ($50 million)	✓ listed as priority area		√

(*Continued*)

Table 2. Continued.

Key adaptation measures	Afghanistan	Bangladesh	Bhutan	India	Myanmar	Nepal	Sri Lanka
Crop residue retention/ conservation agriculture							√
Pest Management /surveillance			√				
Value chain interventions							
Promoting commercial orientation						☑ listed as priority area	
Market for compost/organic manure							√
Postharvest storage			√				
Landscape level actions							
Agroforestry, tree planting and afforestation		√	√	☑ Supported by National Agroforestry Policy		☑ National Agroforestry Policy in pipeline	
Landscape-level measures (eg: rehabilitation and construction of communal water harvesting systems)				☑ $5.5 billion in for actions through National Rural Employment Guarantee Scheme 2015–16			
Marginal land restoration /degraded or waste land conversion			√	√		√	√
Soil fertility management						☑ listed as priority area : targets 4 fold increase in soil organic matter in 20 years	√
Salinity management		√					√
Local varietal conservation	√		√			√	
Ecosystem based adaptation		√			√	√	√
Other actions							
Adaptation research and knowledge management		☑ listed as priority area. Accounts for 7–9% of government's climate related expenditure				√	
Credit/loan for adaptation					√		
Private sector participation				√	√	√	
Institutional frame development for climate adaptation		√	√	√	√	√	√
Monitoring adaptation efforts	√				√	√	

Source: NDC (Afghanistan), NDC (Bangladesh), NDC (Bhutan), NDC (India), NDC (Myanmar), NDC (Nepal), NDC (Sri Lanka).

(Munang et al., 2013), which utilizes landscape-level interventions such as water management (river catchment area protection, ensuring healthy aquifers), sustainable crop management (crop rotation, agroforestry, cover crops, mulching) and strategic management of natural vegetation (protected areas, forest, tree cover). Biodiversity conservation and salinity management are other landscape level adaptation actions. Nepal is also aiming at actions to quadruple the organic carbon content of soils in the next 20 years.

Possibilities to augment the role of agriculture in the adaptation component of NDCs

The agricultural adaptation actions proposed in South Asian NDCs give greatest prominence to green revolution technologies, specifically irrigation infrastructure and stress-tolerant varieties (Table 2). Furthermore, there is more emphasis on maintaining production than on supporting farmers' livelihoods. Only a few countries in South Asia list value chain level adaptation actions focusing on sustaining farm income. By contrast, contemporary global thinking on priorities for adaptation in agriculture place primacy on sustaining and increasing farmers' investment capacity – their ability to invest financial, human and natural capital into their farms, particularly following failures in production due to climatic impacts (Barrett & Constas, 2014; Frelat et al., 2016; Nelson, Lemos, Eakin, & Lo, 2016). As South Asian farmers are predominantly micro-scale farmers, with mean farm size under 0.5 ha, their economic viability can be severely threatened by climatic changes. For example, in India 63% of farms have less than 1 ha, while the threshold farm size to support positive savings is estimated at 2 ha (Dev, 2012). Average farm sizes in South Asia decreased from 2.6 to 1.3 ha in the last 50 years (Lowder, Skoet, & Raney, 2016). The small size of most South Asian farmers' output, leading to inability to make investments, can make them disproportionately vulnerable to adverse weather. This calls for interventions that can increase farm profitability and accumulation of sufficient capital to trigger autonomous adaptations.

Thus, value chain interventions to raise farm gate prices, diversify agricultural markets, increase access to financial services, deploy social safety nets, increase opportunities for off-farm and downstream employment, or promote the flow of market and weather information, are all viable adaptation actions. However, the structural and market-related weaknesses of South Asian farms in addressing investment requirements for adaptation are only weakly represented in the NDCs of South Asia. Some countries do propose value chain actions in their NDCs, which could be further developed. For example, Bangladesh places emphasis on adaptation research, knowledge management and information services, while Nepal identifies value chain development as a priority area though without specifying interventions. While India does not directly list value chain approaches, its national mission on sustainable agriculture, mentioned in the NDC, includes elements to increase remuneration of farmers by market interventions, especially for organic farmers.

There may also be opportunities for better alignment between adaptation and mitigation goals in the agricultural components of South Asian NDCs, by investing in adaptation options that enhance emissions reductions as co-benefits rather than entrenching high emissions development pathways. For example, development of supply chains for manure or organic fertilizers is important if South Asian countries aim to reduce chemical fertilizers and increase nutrient recycling. Given the fact that organic matter constitutes two-thirds of municipal solid waste (e.g. 62% in Mumbai, India, and 67% in Kathmandu, Nepal; Srivastava, Ismail, Singh, & Singh, 2015), actions to recycle the nutrients back to farms can significantly contribute to the goals of reducing fertilizer-related emissions in South Asia. Sri Lanka envisages actions in this direction. Bhutan proposes improving post-harvest interventions, such as cold storage, as an adaptation action in its NDC. A significant reduction in post-harvest losses can be an important adaptation action that benefits both food security and emissions reductions, since losses of up to 16% are noted in South Asian food value chains (Jha, Vishwakarma, Ahmad, Rai, & Dixit, 2015). Landscape-level and ecosystem-based approaches (Munang et al., 2013) also provide options for adaptation that provide mitigation co-benefits – but are only weakly included in South Asian NDCs (Table 2).

Given the complexity and linkages of climate mitigation and adaptation requirements to financial resource requirements, farm structure, natural resource (especially water and soil) constraints, post-harvest storage or processing facilities and market conditions, an integrated body at the national level that can handle multiple roles to coordinate actions along the value chain and among key organizations (e.g. water user associations, rural credit cooperatives) may be a useful innovation in many South Asian countries. Wider institutional approaches to diversify rural income and employment options may also prove to be powerful mechanisms

for adaptation. In India, a unique model is the National Employment Guarantee Scheme of India, which provides 100 days of paid manual labour to willing rural residents. The work goes towards public goods at the landscape level, such as water conservation (terracing, check dams, percolation ponds), drought-proofing (afforestation, watershed management), irrigation (community irrigation systems, canal construction) and renovation of water bodies (desilting of irrigation tanks and ponds). The National Employment Guarantee Scheme is not recognized fully as an adaptation programme due to its core social objective. The labour resource is also allocated to other programmes aiming at productivity and resilience of agriculture, such as the national mission on sustainable agriculture, especially in rainfed regions. The programme can also offset income losses from climatic impacts on agriculture and hence reduce secondary impacts including consumption changes (Amjath-Babu, Krupnik, Aravindakshan, Arshad, & Kaechele, 2016). If it is proved to be cost-effective, the model could be replicated in other South Asian countries and Sub-Saharan African nations such as Burkina Faso, Malawi, Mali, and the Niger, which emphasize the protection of agricultural employment opportunities in their NDCs (FAO, 2016).

Estimates of costs of adaptation actions in NDCs

Among the NDCs of South Asia, only India, Bangladesh and Afghanistan submit adaptation cost estimates (see agricultural adaptation finance needs in Table 3). Bangladesh estimates $18 billion for 2015–2030 and Afghanistan $10.8 billion for 2020–2030. India's NDC gives a multi-sector estimate for cost of adaptation of $206 billion for 2015–2030, which excludes adaptation to extreme events. To derive national estimates (Table 3), we use the adaptation cost figures given in NDCs and NAPAs (National Adaptation Programmes of Action) prepared by the South Asian countries. We make two simple assumptions. First, we assume that all countries (other than India and Afghanistan, where costs are already available) will allocate a similar share of adaptation costs to agricultural GDP as Bangladesh. Secondly, we assume that the cost allocation to agricultural adaptation and disaster management will follow the allocation shares presented in the NAPAs of individual countries. In order to verify the plausibility of the estimates, we have calculated the annual costs per hectare of agricultural land in each country. Using the first assumption, the aggregate cost of agricultural adaptation (including ecosystem level adaptation and forest conservation) without costs of disaster management for 2015–2030 is approximately $302 billion in South Asia or just over $20 billion per year. The largest shares are $206 billion for India and $40 billion for Pakistan. Using the second assumption, based on the NAPA or NDC estimates, the aggregate costs in South Asia, including costs of disaster management, are approximately $528 billion for 2015–2030, or $35.5 billion per year. Notably, India accounts for 63% of these costs.

Previous studies have made comparable estimates of adaptation costs in South Asia. An aggregate figure for India, Bhutan, Bangladesh, Nepal and Sri Lanka (plus the Maldives, which is not included in the current work) is $40 billion per annum, under a scenario of a 2.5°C increase in temperature and 0.3 metre sea level rise, or $31 billion per annum with a 1.9°C increase in temperature and 0.3 metre sea level rise by 2050 (Ahmed & Suphachalasai, 2014). The adaptation costs are not disaggregated to individual countries in this study. IUCN (2011) estimated agricultural adaptation costs in Pakistan of $3 billion per year, compared to our estimate of $2.7 billion per year.

When examined as adaptation costs per hectare of agricultural area, the costs are higher in Bangladesh and Afghanistan, while the others are comparable to each other, which suggests that the estimates are in the plausible range. Irrigation-related investment costs in South Asia are calculated to be around $120 ($165 at 2014 prices) per hectare per year (Nelson et al., 2010), which also shows that the estimates are in the plausible range. In India, the adaptation costs per hectare are calculated to be around $69/ ha, which is less than half of the planned expenditure on afforestation and conservation in India ($174 per hectare of forest per year) reported in its NDC. Across South Asia, the aggregate estimated agricultural adaptation cost is 0.75% of GDP, which will eventually decrease, and when adaptation to natural disasters is included, the share grows to 1.3% of GDP, substantially higher than earlier estimates by the World Bank (2010) of $< 0.2\%$ of GDP.

International comparison of adaptation cost estimates

Among other Asian countries, Mongolia estimates adaptation costs of $3.4 billion during 2021–2030, where 0.83 billion is for agricultural (and forest) adaptations and the rest is to adapt against extreme events. It is around 3–

Table 3. Estimated financial needs of adaptation measures in South Asia (2015–2030).

Details of cost distribution	Afghanistan	Bangladesh	Bhutan	India	Myanmar	Nepal	Pakistan	Sri Lanka
Agriculture and Food Security					Agriculture 16% Health 13%			
Water Resource Management	Irrigation expansion $4.5 billion Watershed management $2.5 billion Rehabilitation of water resource infrastructure $0.75 billion Monitoring $0.1 billion				Water resources 21%			
Ecosystems biodiversity and forestry	Forests regeneration $2.5 billion Conservation $0.3 billion				Forest and biodiversity 47%			
Agricultural Adaptation finance needs	10.8 billion 16.3 billion***	$18 billion	$0.22 billion	$206 billion	$11.98 billion	$4.24 billion	$40.74 billion	$4.8 billion
Annual adaptation finance needs	$1.07 billion	$1.2 billion	$0.015 billion	$13.7 billion	$0.8 billion	$0.3 billion	$2.72 billion	$0.32 billion
Current share of adaptation costs to agricultural GDP (2014 dollars)	21.8%	4.3%	4.3%*	3.8%	4.3%*	4.3%*	4.3%*	4.3%*
share of adaptation costs to total GDP (2014 dollars)	5.1%	0.67%	0.76%	0.69%	1.2%	1.45%	1.08%	0.43%
Agricultural adaptation costs/ha/year[#]	$138	$116	$29	$69*	$61	$67	$72	$111
Disaster Management (Major initiatives)		Comprehensive disaster management $10 billion Salinity intrusion and coastal protection $3 billion Building climate resilient infrastructure $5 billion Urban resilience $3 billion	Disaster management Lake management Landslide protection Flood protection Hazard zoning Early warning systems Forest fire protection	Early warning systems, multi-purpose cyclone shelter, evacuation facilities, bioshields with local vegetation	Early warning systems Coastal area protection			Early warning systems, Development of food buffer stocks, Coastal area protection, fishing vessel tracking

(*Continued*)

Table 3. Continued.

Details of cost distribution	Afghanistan	Bangladesh	Bhutan	India	Myanmar	Nepal	Pakistan	Sri Lanka
Other related actions		Rural electrification $3 billion		Rural electrification	Clean energy (adaptation)			
Aggregate adaptation finance needs including adaptation to disasters	$16.3 billion	$42 billion	$1.12 billion	$332 billion	$19.33 billion	$10.1 billion	$97 billion	$9.99 billion
Share of costs of agricultural adaptation in total adaptation costs[§]	100%	42%	20%	62%**	62%	42% ~	42%~	48%
Share of total adaptation costs to GDP	5.1%	1.65%	1.12%	1.08%	1.9%	3.5%	2.6%	0.9%

* the share is assumed to be similar to Bangladesh.
** the share is assumed to be similar to Myanmar.
*** extrapolated to 15 years.
[#] Exclude disaster management costs.
~ the share is assumed similar to Bangladesh.
[§] Calculated based on NAPA or NDC.
Data Sources: NDCs (http://www4.unfccc.int/Submissions/INDC/Submission%20Pages/submissions.aspx) and NAPAs of South Asian countries (http://unfccc.int/adaptation/workstreams/national_adaptation_programmes_of_action/items/4585.php), UN (http://data.un.org/), World Bank (http://data.worldbank.org/), Climate Public Expenditure and Institutional Reviews (Nepal, Bhutan, Bangladesh, Pakistan), Own Estimates.

4% of agricultural GDP and $63/ha, which is comparable to South Asian countries. Several African countries have estimated costs of adaptation (Richards et al., 2016), ranging from $5/ha (Mali) to $55/ha (Zambia) and 0.6% of agricultural GDP (Uganda) to 9.5% of agricultural GDP (Madagascar). Compared to South Asia, the generally higher costs of adaptation in Africa in terms of share of GDP, and lower costs in terms of cost per hectare, reflect the extensive cultivation systems of the African continent. Comparative figures are not available for South American countries. Their economic context differs from South Asia or Africa as the contribution of agriculture to total GDP is less than 10% in most countries in the region.

Financing of NDC actions in agriculture

In the case of India, the climate finance requirements are to be met through budgetary, market and regulatory channels and through international funding sources. The major domestic financial source for mitigation actions are the National Clean Environment Fund, realized through a cess (tax) on coal ($3.2/tonne), which provided $4 billion over the period 2011–12 to 2015–16. In 2016–17, the aggregate coal tax amounted to $4 billion, as the cess was increased to $6/tonne. The equivalent for adaptation efforts is the National Adaptation Fund, which allocated $55.6 million in 2015. India also spent $5.5 billion (2015–2016) for the employment guarantee scheme that can also be considered as a part of adaptation (landscape-level) financing. The Company Act in India directs a mandatory Corporate Social Responsibility (CSR) spending amounting to 2% of annual company profits. It is expected that $3.5 billion annually will be invested in India in private CSR-related environment initiatives, including activities to adapt to, and mitigate, climate change. Given the adaptation costs around $13 billion per year, the adaptation finance gap could be around $9-$10 billion per year, which will only be partly met by international financing mechanisms. Given that the global adaptation finance realized in 2014 was around $25 billion (UNEP, 2016), it cannot be expected that the gap will be closed by international financing options, pointing to the need for large-scale autonomous adaptation in the country.

Nepal envisages bilateral and multilateral grant support and participation in carbon markets (in the case of forests) in addition to budgetary resources. The government of Bangladesh is currently spending $1 billion per year for climate change adaptation, which is around 6–7% of its annual budget (GoB, 2012; UNEP, 2014). Bangladesh reports that a new Climate Fiscal Framework (CFF) will be integrated in the national planning and budgeting process to determine the financial requirements of mitigation and adaption options. The country expects international finance, technology transfer and capacity building to bridge the gap in financial and technical capacity to undertake mitigation and adaption actions.

Bhutan is integrating the proposed actions in its five-year plans and expects financial and technical support from international climate mechanisms. In the case of Myanmar, technology transfer relating to renewable energy, energy efficiency, flood control and early warning systems is of considerable interest, calling for substantial support from the international community. Myanmar currently does not allocate a significant part of the domestic budget to climate change adaptation. Similarly, Sri Lanka has no specific plans or policies focusing on climate change adaptation, though there are some related actions in water and soil conservation (CCS, 2015). Afghanistan envisages support from the Global Environment Facility (GEF), the Green Climate Fund (GCF), and other international climate finance institutions to support its mitigation and adaptation funding requirements. Pakistan already recognizes the large adaptation funding gap and proposes debt swaps for adaptation that can free funds from national debt commitments that can be directed to adaptation funds (Amir, 2011) as one of the mechanisms to reduce the gap, in addition to other funding channels (not stated in its NDC).

Conclusions

This research assesses South Asian countries' commitments to agricultural adaptation and mitigation, in their NDCs and related policies, in the context of food security. Currently South Asian countries position agriculture as a major victim of climate change downplaying the role of agriculture in emissions reductions despite its considerable share in aggregate GHG emissions. While there is potential for emissions reductions that do not compromise food security or agricultural development, the difficulty in developing economically-beneficial agricultural mitigation technologies is a crucial bottleneck, and hence a priority for South Asian governments.

Technologies such as algal production in paddy fields or co-location of agriculture and solar energy production are examples of such technologies. Research and development, technology transfer and scaling-up in these technologies could greatly enhance the potential of agriculture as a sector for mitigation in South Asia, bringing these countries closer to their aspirations for the Paris Agreement. Provision of direct incentives (carbon payments) for emission reduction effort in agriculture may also support large scale adoption of available mitigation technologies but overcoming high transaction costs (due to small farm size) for such payment mechanisms can be a challenge in deploying such interventions.

In the case of adaptation, interventions to protect the cornerstones of the green revolution – high-yielding varieties and irrigation – take the major share of proposed adaptation expenditure by South Asian governments. The large majority of investments aims to expand irrigated areas, increase efficiency of irrigation and develop stress-tolerant high-yielding varieties. Given the lessons from soil degradation caused by intensive agriculture under the green revolution, governments recognize the need to arrest soil degradation and envisage increased replacement of fertilizer by nutrients from organic sources. But these plans are difficult to realize without development of supply chains for organic manure and increased recycling of nutrients from urban organic wastes, yet no major initiatives are reported in this direction.

It is also clear that the countries do not consider inherent structural and market-related weaknesses of their farming sectors in their NDCs. Structural interventions that address farm size, profitability and accumulation of farm capital must underpin any NDC if South Asian countries are to trigger autonomous adaptations by farmers and achieve adaptive capacity and transformed farming systems at the necessary scale. The structural problems are compounded by imperfect output markets that lead to low value realization of farm produce and imperfect credit markets that increase the credit burden (Dev, 2012). A shift of policy focus from productivity to profitability of farming is required to address the market issues that are likely to hinder adaptation efforts. Only a few countries report actions on agricultural value chains in their NDCs. In addition, the increasing role of women in agriculture is largely ignored in NDCs and no specific programmes that target women farmers and address their specific needs in adapting to climate change are listed. More integrated approaches, led by integrative institutions, will be critical to delivering sustainable adaptation at scale.

Despite their current shortcomings, the NDCs show considerable scope for learning from each other's efforts in achieving adaptation goals. The basket of adaptation actions among South Asian countries includes both ecosystem-based adaptation and landscape-level efforts to increase climate resilience. The labour compensation model (generating rural employment) for landscape-level interventions in India can be a good example of how climate adaptation or mitigation objectives can be supported with actions with core social goals.

Most of the countries are unable to project financial needs for adaptation, except Bangladesh, India and Afghanistan. This paper attempts a plausible estimate using simple assumptions. The projection shows financial costs of agricultural adaptation in South Asia of $302 billion for the 2015–2030 period, or $528 billion when costs of measures to adapt to climatic disasters are included. These projected costs are in agreement with available alternative estimates and thus, despite their simplistic method, may be used as best approximates where there are no available individual country estimates. Currently, available financial resources fall well short of needs. India is attempting to raise the domestic resources available through carbon taxes and private financing via mandatory corporate social responsibility schemes. Countries like Pakistan may be able to use similar instruments, but most of the other countries may need sizable intentional funding for mitigation and adaptation. Scaling-up of international financing, as well as promoting autonomous adaptations by addressing structural and market related weaknesses in the agricultural sector, will be crucial to achieving the agricultural adaptation goals of South Asian countries and hence securing food security for a quarter of the global population.

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