Appendix: Description of five exemplary WEF nexus cases

Case 1: Food and energy production in an integrated livestock system in Forish district, Uzbekistan

System boundaries, WEF problem and objective definition: Forish is a district in Djizzakh province of Uzbekistan with about 780 km^2 area, where livestock is a main source of income though prolonged overgrazing has resulted in land degradation. In addition, a lack of fossil energy sources has driven local villagers to start using natural resources (e.g. firewood, shrubs, manure) for cooking and heating purposes. Combined, these two elements have further aggravated land degradation as manure is no longer available to improve soil fertility due to the decline in livestock and shrubs are no longer available for shading and grazing. Land degradation has deteriorated water storage capacity of the soils which in turn result in erosion and desertification (Abdurahmanov 2015). The main objective of this case study was to reverse land degradation and improve water storage and availability through alternative energy utilization.

Scenarios: Three scenarios for alternative resource management were considered: (1) develop public infrastructure to gain access to remote grazing areas, (2) use integrated livestock management to improve grazing conditions and livestock quality (including, potential bioenergy production), and (3) promote ecological tourism to develop alternative income sources and reduce pressure on land resources.

Impact areas: Six indicators were considered for the impact assessment: (a) pasture carrying capacity; (b) quantity of dung for heating; (c) alternative energy production options; (d) availability of drinking water; (e) work opportunities; (f) food production. Through the six indicators the group addressed WEF relevant SDGs 2, 6 and 7. Additionally, impact areas related to decent work and economic development (SDG 8) as well as pasture management (SDG 15) were addressed.

Results: The findings reveal that the integrated livestock management scenario was the best option with regards to most indicators (Table 2). However, the scenario provided fewer job opportunities and the availability of drinking water was reduced. The ecological tourism scenario only scored well for the provision of job opportunities. The scenario of improving public infrastructure was ranked between the two. Although each scenario contributed to improving the quality of life, integrated livestock management increased energy sources, employment options, industrialization, food availability and pasture restoration, and also mitigated grazing land degradation. If no intervention is done in the district, the grazing land is expected to further degrade and may cause ecological and social deterioration.

Case 2: Hydropower construction impacts on land and water management in Yakawalang district, Afghanistan

System boundaries, WEF problem and objective definition: Yakawalang is mountainous and one of the largest district of Bamyan province in Afghanistan with an area of approximately 3,980 km^2. The main source of income in this district is livestock production and irrigated agriculture. Water shortage, soil salinity, low crop productivity, lack of access to sustainable electricity and soil erosion are significant challenges. The government of Afghanistan has recently suggested to construct a hydropower plant with a dam reservoir on the Band-e-Amir River in the district to provide electricity, which may have implications for water availability for irrigation in terms of quantity, quality, reliability and timing of water delivery constituting a typical WEF nexus constellation. As the mountainous area is very vulnerable to soil erosion, the dam can be expected to quickly suffer from siltation and loose its capacity if construction was not accompanied by soil conservation management practices. The objective of this study was to conduct an ex-ante SIA of alternative land management scenarios in order to maintain functioning of the water regulation for stabilizing food and energy production in the study area.

Scenarios: The study tested three scenarios that included hydropower construction with: (1) no land management, (2) government managed forests and pastures (mainly restoration), and (3) community managed forests and pastures (restoration plus management).

Impact areas: Three impact areas were selected, focusing on water availability for irrigation (SDG 6), hydropower production (SDG 7) and soil erosion (SDG 15). Food production was indirectly addressed via the soil erosion indicator. Soil erosion prevention measures such as afforestation would reduce available area for food production but could increase soil quality and therefore productivity on the remaining land, particularly at long term.

Results: The results indicated that in scenario 1 (no land management governance), dam development would not take into account soil erosion issue and reservoir would steadily accumulate the sediments transported from upstream. This would reduce the effective capacity of the reservoir, which may lead to either reduced hydropower generation or higher operation costs in the long term. Scenario 2 (government managed land) provided better benefits in the short to medium term due to reduced soil erosion, and with less sediment accumulation in the reservoir. Nevertheless, unclear ownership rights issues over newly forested areas would be expected to lead to classic common-pool resource dilemma in which would lead to either a gradual decline in the forest density with time or impose additional operation expenses in terms of forest protection services. Under scenario 3 (community managed land), the sustainability of forested areas was expected to be secured through endowment of the local communities with ownership rights. This scenario offered better prospects for hydropower generation and irrigation supply regulation due to relatively greater reductions in soil erosion and prevention of sediment accumulation in the reservoir. The total net benefits of this scenario were estimated to be larger than the two scenarios, with it addressing the needs of both downstream and upstream communities.

Case 3: Water use across food and energy sectors in Tashkent Province, Uzbekistan

System boundaries, WEF problem and objective definition: Located in the northeastern part of Uzbekistan, Tashkent province receives water for irrigation purposes from the Tien Shan Mountains through Chirchik River and has an area of about 14,480 km^2. This river has 19 hydropower plants which produce about 54% of the total hydropower energy in Uzbekistan. Water is the limiting factor for economic development in Tashkent province, which hosts about 9% of the 33.8 million inhabitants of Uzbekistan. Considering current energy demand, the future industrialization potential even drastically increasing energy demand, and the important role of the province in providing food security for Uzbekistan, the aim of the study was to carry out a SIA of alternative water utilization scenarios for economic development of the region.

Scenarios: Three scenarios were developed: (1) business as usual, meaning lack of timely irrigation water delivery to farmers and poor environmental quality in the region, (2) water use for food production to allow intensification of agriculture, and (3) water use for energy production to strengthen industrial processing.

Impact areas: Eight impact areas were identified addressing WEF sectors: food production and processing and total irrigated area (SDG 2); water demand (SDG 6); energy production (SDG 7); human health and education (SDG 3); employment and work opportunities (SDG 8); sustainable urbanization (SDG 11); and environmental health (SDG 15).

Results: Scenario analysis results indicated that the industrial processing and the agricultural intensification scenarios were better options for the province. Although it was difficult to prioritize the use of water for energy in the industrial processing scenario or to use for food production with the agricultural intensification,

the study concluded that the current business as usual scenario was least suitable for sustainable development.

Case 4: WEF nexus governance cooperation between Tajikistan and Uzbekistan: Case of Amudarya river basin

System boundaries, WEF problem and objective definition: This case study dealt with the collaboration between upstream Tajikistan and downstream Uzbekistan in the governance of the WEF nexus of the Rogun dam area (ca. 17,400 km^2), a sub-basin of the Amudarya river. Uncoordinated construction of the Rogun dam for hydropower purposes, originally started in 1982 in Tajikistan (Menga and Mirumachi 2016), affects water utilization options for irrigated food production in Uzbekistan. This aim of the SIA was to explore the governance of WEF nexus in the Amudarya river basin to seek regional solutions to common challenges.

Scenarios: Three scenarios, representing different degrees of cooperation between upstream country Tajikistan and downstream country Uzbekistan in the WEF nexus governance, were developed: (1) full cooperation, (2) partial cooperation, (3) no cooperation.

Impact areas: The study covered all three WEF-related SDGs of agricultural production (SDG 2), irrigation water quality as well as clean water supply and sanitation (SDG 6); energy production (SDG 7); as well as employment rate (SDG 8); and the provision of ecosystem services (SDG 15).

Results: Results showed that both countries would benefit from mitigating tradeoffs and maximizing synergies when they fully cooperate. Under full cooperation, the downstream country Uzbekistan would be better off in all indicators while the upstream country Tajikistan would face trade-offs regarding water quality, energy and agricultural production. It would however also gain in terms of environmental and social aspects. Overall, Tajikistan would not be affected much by the degree of collaboration, whereas Uzbekistan highly depends on the degree of cooperation.

Case 5: Water management across five countries of the Amudarya river basin

System boundaries, WEF problem and objective definition: The Amudarya basin is the largest river basin in Central Asia with an area of 520,000 km^2 (Djumaboev et al. 2020). The basin is characterized by a complex political situation due to the transnational competition between water for agriculture and water for hydropower. Moreover, using lift irrigation to produce food and cultivate cotton in downstream countries is highly energy consuming and exacerbates the challenges. The case developed and analyzed transboundary governance scenarios for shared water management in the Amudarya river basin, explicitly considering future climate change.

Scenario: Two scenarios were assessed: (1) business-as-usual and (2) transboundary cooperative water management between five countries Afghanistan, Tajikistan, Turkmenistan, Kyrgyzstan, and Uzbekistan.

Impact areas: Out of the three WEF–related SDGs only food production (SDG 2) was explicitly addressed with the indicators agricultural land change and vegetation period change. In addition, living standards (SDG 3) in affected countries and the quality of the terrestrial ecosystem (SDG 15) were addressed, the latter via three indicators: ecosystem service provision, occurrence of extreme events, and biodiversity.

Results: The assessment found that the benefits gained from cooperative, transboundary governance surpassed the benefits acquired from individual, national level governance. In particular, the management of extreme events, which are expected to become more frequent because of climate change, was found to be more effective with transboundary cooperation. Benefit sharing mechanisms during transboundary water

resource management could result in new profitable options for economic development. The results can be used for the demonstration of importance in regional cooperation.