Water Management and Ecosystem Services:Peru Management Guide

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Water Management and Ecosystem Services

This guide provides contextual information regarding ecosystem services that influence the supply and management of water resources in the Virú valley region of Peru. The document, developed by JNCC, demonstrates how the ecosystem service maps produced by Environment Systems for the EO4cultivar project[1] can be used to help inform decision making through the implementation of ecosystem-based management**.**

Water as an Ecosystem Service

A clean, reliable and well-managed water supply is critical to sustain life. It is required for the majority of biological and industrial processes, for example: drinking water; agricultural irrigation; industrial cleaning and cooling; climate regulation; and weathering and soil formation.

The functions that water provides that are of societal and ecological importance can be categorised under different ecosystem service typologies.

Provisioning ecosystem services include:

- Clean water for human consumption and crop irrigation.
- Critical component in sanitation systems for preventing spread of animal and plant pathogens.

Water is associated with regulating and maintenance services, including:

- Supporting ecosystems that drive nutrient cycling and carbon sequestration.
- Hydrological cycles drive weathering processes in minerals, soils and rocks, contributing to soil formation and making micronutrients available to support ecosystems.
- Pollutant assimilation, wetlands in particular break down and disperse pollutants and help maintain good ecological status of ecosystems.

Provide cultural ecosystem services:

- Lakes, rivers and oceans provide countless recreation opportunities.
- Proximity to water has a positive impact on human health and well-being.[2]
- Water is likely one of the only natural resource linked to all aspects of human civilization and culture.[3]

Water usage in the agricultural sector

Water is a vital natural asset to the global economy. The major water demand in Peru's Pacific hydrological basin is the agricultural sector, accounting for 86% of usage.[4]

Asparagus is one of Peru's most common crops, with production being concentrated on the coastal regions of Ica and La Libertad.[5] Peru is the largest exporter of asparagus in the world, generating over US$450 million a year from the trade.[6]

Unlike national competitors, Peru is able to harvest asparagus all year round. However, the water requirements of asparagus far surpass other agro-exports, requiring between 14500-16000 m^3/ha/yr of water.[7, 8]

Advances in water technology, including drip irrigation in the 1980s and large-scale irrigation schemes in the 1990s, has made it possible to expand agricultural production into more arid regions. In Trujilo and Viru, 99% of agricultural land (~ 37,000 hectares) is under irrigation.[9]

Water supply in the Virú valley region

Peru's Pacific coastline stretches for 2400km² and the Amazon River originates from the Solimos River draining the Northern Peruvian and Ecuadorian Andes, and the Madeira River draining the southern Peruvian and Bolivian Andes.[10] Peru also contains 71% of the tropical glaciers in South America. This unique combination of geography and hydrology provides surface, ground and atmospheric water and accounts for 4.6% of the volume of the world's run-off. Most surface run-off occurs in the rainy season with approximately 80% of water flow in the Pacific Basin occurring between December and April.[11]

The Peruvian coast is supplied by ephemeral moisture from clouds formed over the Pacific Ocean that drift inland and sweep over the desert slopes producing fog. The fog isn't wet enough to produce rain, but the water contained in fog is substantial and fosters formations of fog-drip vegetation known as lomas.

The lomas is an ecosystem with two distinct seasons, a dry season and a humid season (May to October) where elevational fog condenses to provide moisture to vegetation. During El Niño events, high precipitation occurs throughout the year, causing constant vegetation presence, especially of ephemeral herbs.[12, 13] During periods of fog, the taller trees of the lomas collect tiny water droplets on their trunks and leaves that filter into the surrounding soil. In some areas of Peru, this fog helps sustain local communities who capture the fog in nets to collect water for drinking and crop irrigation.[14, 15]

The Virú River Basin spans across the provinces of Santiago de Chuco, Julcán and Virú. The Virú River supplies the Virú Province.[16] The Virú River has a low average discharge rate (the volume of water which flows through it in a given time). This traditionally meant that farmers relied on the pumping of groundwater from aquifers to water their crops. To increase water availability, a large-scale irrigation project, the Chavimochic Project, was designed to create trans-basin water transfer by connecting four river valleys in La Libertad - the Chao; Virú; Moche; and Chicama - via an irrigation canal (Figure 1). The increase in flows were created by diverting surface water from the Santa River into the four smaller river basins. The Santa River is fed by glaciers in the Cordillera Blanca, which has the highest concentration of tropical glaciers in the world. This has allowed for the extension of the agricultural frontier by 46,700 new hectares, and the improvement of irrigation for an additional 28,300 hectares.[17] The Chavimochic Project also provides drinking water to the city of Trujillo and surrounding districts.[18]

Figure 1. Chavimochic Project connects four river valleys in La Libertad, the Chao, Virú, Moche, and the Chicama, via an irrigation canal. The first two phases of the project are complete, costing US$1.29bn. A third phase is planned, including constructing a 360 million m³ reservoir in Palo Redondo, a third line of the Virú water pipeline and 113km Moche-Chicama-Urricape water channel.

Adopting a Landscape Approach to Water Management

Commercial crop growers are amongst the main water users within the area of interest. Regional producers and the Chavimochic Centre for Productive Innovation and Technology Transfer (CITE) have engaged with the EO4cultivar project. Through a number of stakeholder meetings, the project explored how adopting an ecosystems approach could contribute to sustainable water management and how modelled outputs could demonstrate how partner organisations can use earth observation data to identify, understand and report on environmental and natural resource risks and opportunities affecting their production systems and supply chains.

Ecosystem-based management can help manage water quality, availability and quantity. Different ecosystems can play a critical role in reducing water flow rates, act as water stores, as well as filtering out nutrients and heavy metals. Working with nature can help delivering multiple ecosystem services through nature-based solutions.

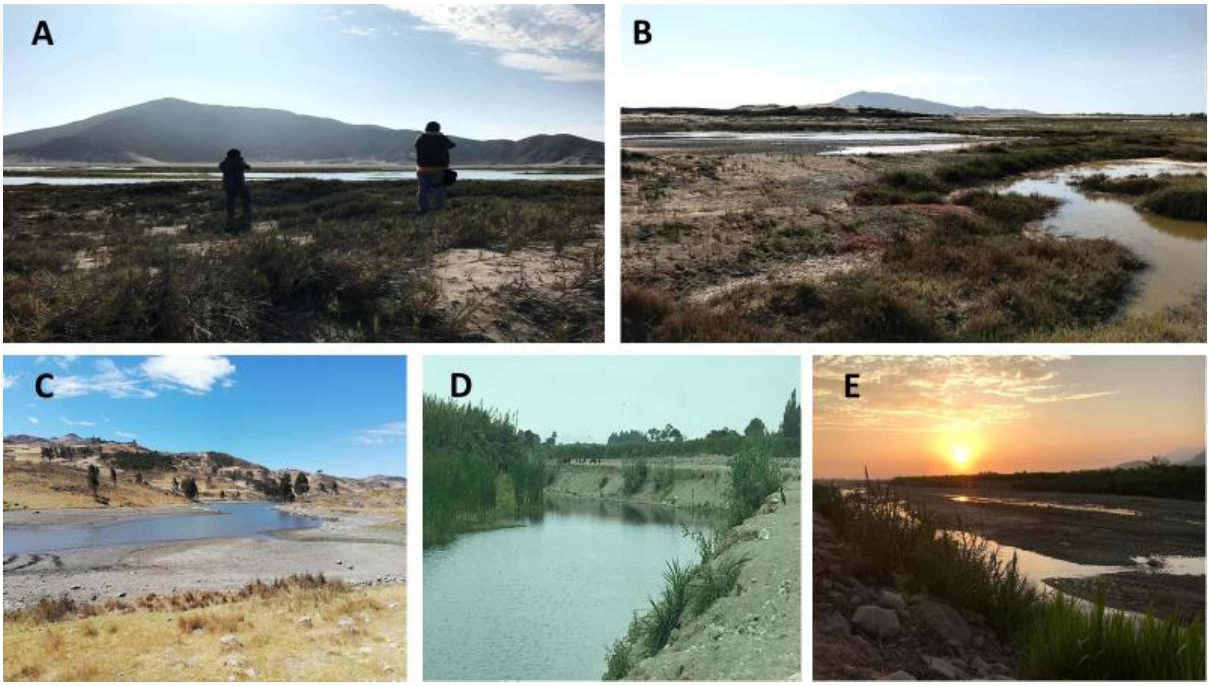

Figure 2. The Viru Valley comprises a range of different wetland and coastal ecosystems. This include coastal wetlands [A] and salt marshes [B] that are rich in bird life and offer protection from coastal erosion and sequester atmospheric carbon dioxide, helping mitigate climate change. There are different types of water bodies, classed as 'water regions' throughout the landscape [C], as well as permanent river channels [D] and ephemeral channels where water levels vary seasonally [E].

Using Ecosystem Service Maps to Inform Management

The ecosystem service maps are designed to demonstrate the functions that natural ecosystems play in maintaining and regulating water supply. They are aimed at supporting land-use planning, promoting sustainable ecosystem management to increase the long-term resilience of production systems. The maps provide an evidence-base for community and stakeholder engagement.

Maps in the EO4cultivar sustainable livelihoods portfolio[1] directly relevant to water management include:

Ability of the land to moderate surface water runoff - This map shows areas where the landscape can provide natural flood management through hydrological and morphological processes working together with habitat features to manage water runoff. The map was created by assessing geology, soil, slope, habitat and management. These attributes reflect the contribution of specific areas to natural regulation of overland flow which is affected by infiltration and interception rates; water storage capacity and sediment load control. The map can be used to target protection or enhancement of priority areas that limit surface runoff and prevent flooding

Opportunities to enhance surface water regulation and places receiving high volumes of surface water flow - These two separate maps can be used to identify areas where there are potential opportunities to consider different management to enhance water regulation in upper, mid and lower areas of the Virú Valley. The areas identified are hydrologically connected, whilst management of water regulation in the upper catchment can benefit a larger area, feasibility of interventions at different sites needs to be considered.

Ecological Network Connectivity - Wetland Ecosystem - This map shows the existing network of wetlands and rivers, these are areas of native and semi-natural wetland habitats that are connected within the landscape. Areas of high connectivity, with low chemical and nutrient levels, and high structural and species diversity are more resilient to environmental changes, such as fluctuations in temperature or precipitation. Such areas provide higher level of ecosystem service provision such as clean water and erosion control. The map could be used to ensure that any agricultural practices or land use changes do not reduce ecological connectivity further and impact ecosystem services and biodiversity.

Opportunities to deliver multiple ecosystem services: ecological connectivity and surface water regulation - The map shows places where it should be possible to restore or create new habitat to strengthen existing ecological networks and simultaneously enhance surface water regulation.

Places delivering multiple ecosystem service benefits; key areas for biodiversity and surface water regulation - The map identifies areas of source habitat (scrubland, woodland, wetland) which is biodiverse, and which coincides with areas providing high surface water regulation. The structure and 'naturalness' of the vegetation provides high biodiversity value. These vegetation characteristics combine with characteristics of the soil, geology and slope enables the identification of areas that also provide high levels of surface water regulation. This is a form of natural flood management, where hydrological and morphological processes, together with the habitat features, work together to regulate the sources and pathways for flood waters. Places providing high levels of multiple ecosystem services could be considered more valuable than those providing a single ecosystem service.

Table 1 provides examples of how the mapped outputs can be used to inform ecosystem-based management measures to help manage water and maintain ecosystem services critical to sustainable agricultural yield.

Delivery of benefits to increase the sustainability of production:

Measure type	How to use the map	Affiliated management option
Restore riparian buffers	Use the Ecological Network Connectivity - Wetland Ecosystem map to identify the wetland network source. Compare this to the opportunities to deliver multiple ecosystem services map to identify areas along the river margins where it should be possible to restore or create new habitat to strengthen the existing wetland or woodland ecological networks to enhance biodiversity, while simultaneously enhancing the level of surface water regulation.	The degree to which the riparian buffer protects water quality is a function of the area's hydrology, soils, and vegetation. In areas where slope is minimal and surface water flows are slow and uniform, riparian areas can be highly effective in slowing the force of stormwaters and reducing the amount of sediment, crop debris, and other particulate materials that reach streams and irrigation infrastructure.[19, 20]

Measure type	**How to use the map**	**Affiliated management option**
Constructed Wetland creation	Use the opportunity maps to identify areas that provide opportunities to improve water regulation. Within these areas, select unproductive land where wetland habitat can be created. Consider how the intervention will provide benefits to production areas and local communities through reduced flood risk. Also consider where wetland construction can enhance key areas for biodiversity and ecological connectivity by consulting ecological connectivity maps.	Creation of new, or expansion of existing, wetland habitat can slow water discharge into river channels and prevent flood water surges; retain water for use in irrigation; act as natural filtration by removing chemicals and sediment before water enters channels. Wetlands can also be used to enhance biodiversity; consideration can be made to encourage species beneficial to production (i.e. crop pest predators and pollinators). It is important to consider these actions in relation to crop health, ensuring habitat creation encourages a balanced ecological community structure and not one that could provide a source of pest species outbreak.
Create meanders in the main channel	Use map of wetland connectivity and satellite images to identify focal areas for potential re-meandering interventions. Meanders can also help improve ecological connectivity between wetland habitats.	Flood prevention measures often result in building concrete defences to contain water. If defences fail, the level of damage can be increased. Creating meanders in head waters can slow the rate of water discharge, reducing pressure on defences further down the catchment.[21] Meanders can also improve the attractiveness of the landscape, offer recreation areas and provide habitat for animal and plant species.
Create additional water storage facilities (e.g. micro dams and flood storage reservoirs)	Use maps highlighting areas with a low or moderate contribution to surface run-off along with maps showing areas delivering multiple benefits. Consult maps highlighting opportunities to improve water regulation and look for areas of overlap.	A flood storage reservoir is an artificially raised body of water used to store water temporarily. Improving rainwater storage and capture service in the headwaters basins and sub-basins to mitigate the impacts and adverse effects of change climate such as flood risk. Micro dams can be constructed of wood or rocks and act to deflect and diverter water. Dams can be designed to suit the location and use local and natural materials. They can be easily installed at low cost and designed to offer multiple benefits for managing flooding and wildlife.[22]

Measure type	How to use the map	Affiliated management option
Conservation and rehabilitation of ancient terraces	Use the ability of the land to moderate surface water runoff map to identify areas in the upper catchment that have the right geology, soil, slope, habitat to provide natural flood management. Compare this to Ministry of Agriculture's Rural Agricultural Productive Development Program (AgroRural [23]) inventory of agricultural terraces to identify areas where abandoned terraces are present and could be restored.	Terraces in the upper catchment are used by smallholder farmers to grow crops such as avocados and blueberries. Terraces are very efficient at conserving scarce water from rain or irrigation canals and so increase water availability in the soils and aquifers, allowing higher crop densities and subsequently higher yields.[24, 25] The supporting walls of terraces should be strengthened or rebuilt, and the terraces should be replanted with vegetation. This will avoid soil erosion and the risk of large quantities of sediment being washed into water courses during storm events as well as the threat of landslides.[26] AgroRural's 2010 systematization and inventory of agricultural terraces catalogued 340,719 terraced hectares, of which 259,319 hectares were in use and 81,400.06 hectares abandoned.[27]
Restore ancient irrigation systems (amunas)	Use the opportunities to enhance surface water regulation to identify places in the upper and mid catchment that are receiving high volumes of surface water flow and where canals could slow the flow down the mountainsides.	1,400-year-old systems of stone-lined and earthen canals in the Andes highlands channel excess rainwater from streams into sandy, rocky zones. The water filtration ability of soils stores water beneath the surface and reduces overland flow from the steep slopes during the wet season and reduces the risk of floods. By slowing the speed, water reaches downstream springs later and is available during the dry season. One study found on average, water took about 45 days to flow through the canals and underground channels to reach springs.[28, 29] Such a canal system relieves some of the demand on reservoirs, dams, and other infrastructure.

Measure type	How to use the map	Affiliated management option
Plant and conserve Lomas vegetation	Consult habitat map to identify areas that may signify the presence of lomas vegetation i.e. areas of sand dune with vegetation, dense and scattered scrub/bush, and vegetated erosion gullies. Lomas occur on small mountains or steep coastal slopes (< 1000 m a.s.l.) separated by flat hyper arid desert.[30, 31] Consult maps showing opportunities to enhance ecological connectivity to identify types of habitat that could be restored. Once potential restoration areas have been identified arrange a site visit to determine if areas are suitable.	It's estimated that the South American lomas support some 1,400 plant species, more than 40% of which are found nowhere else. A typical lomas mostly has annual herbs, but also perennial herbs, and a few woody plants. One tree in particular has proved critical for capturing fog — a small but sturdy tree with leafy branches known as *Caesalpinia spinosa*, or tara tree. Reintroducing the tara trees, can create favourable conditions for other species as well.[32] Unmanaged cattle grazing is one of the main threats to this habitat. Local herders should restrict the use of lomas as forage for their cows, goats and sheep. Technology is also being developed to increase the efficiency in obtaining water from fog by improving the design of fog-catching facilities.[33, 34]
Reforestation and afforestation in the upper catchment	Consult habitat map and map showing areas contributing to surface water run off to identify habitat types contributing to water regulation. Consult maps showing opportunities to enhance ecological connectivity to identify types of habitat that could be restored. Identify areas for site visit to identify areas, stakeholder and additional ecosystem and societal benefits that could be delivered from restoration activities	Promoting the reforestation of upper catchments can: increase water capture and aquifer recharge within the hydrographic basin and increase water availability downstream; stabilise the land and reduce soil erosion; and filter sediments and pollutants.

Measure type	How to use the map	Affiliated management option
Cover crops and mulching	Use the habitat map to identify agricultural areas. Consult water regulation maps to identify areas delivering negligible water regulation. Consider mulching and cover crop planting in these areas to enhance water regulation capacity.	Mulching using organic material (e.g. bark, wood chips, pulp, shell nuts, green waste, leftover crops, compost, manure, straw, dry grass, leaves etc.) to cover the surface of the soil can significantly increase the capacity of soil to store water.[35] A cover crop is a crop that is grown between main crops and can assist in protecting soils, reduce flood risk, and improve subsequent crop yields. Other benefits of cover cropping include soil stability and erosion reduction, reducing chemical leaching through run off, improved soil structure and infiltration, increasing organic content, improving water quality and retaining soil nutrients.[36]
Crop rotations	Use the habitat map to identify agricultural areas. Consult water regulation maps to identify areas delivering negligible water regulation. Consider crop rotation potential in these areas to enhance water regulation capacity.	Selecting particular crops on a seasonal rotation can improve soil structure and fertility by alternating plants that have different root depths. This can reduce erosion and increase infiltration capacity, helping reduce downstream flood risk.[37, 38]
Anticipate environmental risk exposure and mitigate against the impacts	Use the opportunities to enhance surface water regulation map and the opportunities to deliver multiple ecosystem services map and compare them to the risk of soil erosion map to identify areas vulnerable to extreme events such as flooding or landslides.	Peru is at risk from more variable precipitation and more frequent El Niño – Southern Oscillation (ENSO) events due to climate change.[39] Proactively mitigating against environmental risks using habitat restoration and natural flood management techniques (such as those listed above in this table) will help to reduce the social and economic impacts of extreme natural events.

Knowledge requirements to inform water management

Changing global conditions make water resource management increasingly complex. Factors to consider when planning a water management strategy should include issues such as:

- Population number and demographics
- Increasing urbanisation, industrialisation and economic development
- Changes in environmental quality and conditions
- Ecosystem water requirements
- Changing societal attitudes and perceptions

These factors are interrelated and information and data on these dynamics, and their interactions, should be considered in addition to earth observations and ecosystem modelling.[40]

Water management policies and plans all over the world often adopt a sectoral focus and fail to consider future environmental pressures and drivers from other sectors that may affect water management. Integrated Water Resources Management and Integrated River Basin Management must take a wider view on water related issues, at the macro and meso scale, to develop sustainable and achievable solutions. To attain this, water managers need to consider[41]:

- Collaboration to achieve policy compliance
- Establishing transboundary partnerships
- Stakeholder participation and co-design of strategies
- Developing local capacity to meet compliance
- Obtaining political buy-in and administrative support
- Adopting new tools and techniques

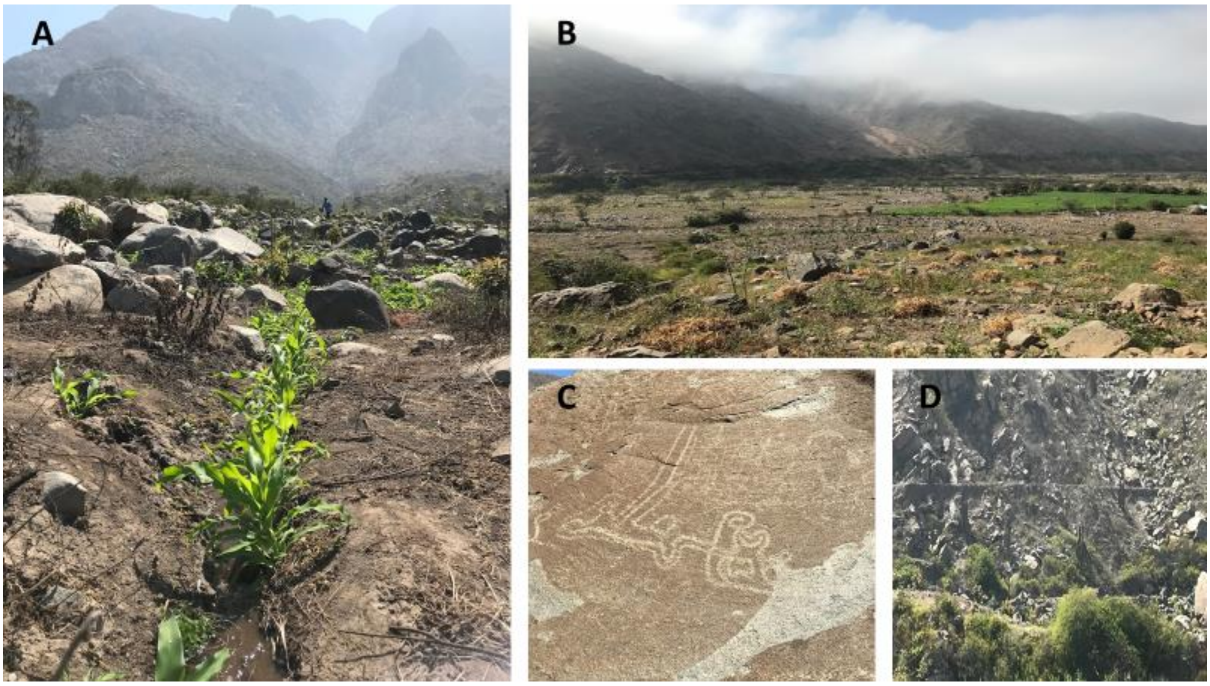

Figure 3. The upper catchment of the Viru Valley contains irrigation terraces installed by the Moche Civilisation (100-700 AD) that continue to fed by natural springs flowing from the mountains [A]. The ecosystems in the upper catchment is important for capturing atmospheric moisture, which condenses on vegetation and recharges soil moisture and aquifers [B]. There are signs humans managed the upper catchment for millennia, with signs of stone drawings that locals suggested could be irrigation planning [C] and ancient irrigation channels hewn into the mountain side [D] to carry water into the lower catchment to feed the crops of past civilisation.

Pressures Affecting Water Ecosystem Services

The ecosystem services associated with water can be compromised by different abiotic, biotic and anthropogenic factors. Those that are particularly relevant to the case study area are:

Population pressure

A recent study found that the main driver of increased water stress in the tropical Andes is population growth, which may increase water demand by up to 50% in 2050.[42] Peru's coastal Pacific basin is under the greatest water stress of the country's three hydrographic regions. It accounts for 65% of the population and more than 80% the country's GDP, yet only has access to 1.8% of the country's renewable water resources.[43, 44] Given that the population of Peru is expected to rise by 27% between 2015 and 2050 and drinking water supply is given priority over irrigation, this may place further pressure on agricultural supply.[45] This is in addition to water competition between other sectors such as industrial supply, hydrological energy production, mining and livestock.

The mass migration of people from rural areas to coastal cities has caused around half a million of Peru's poorest and most vulnerable people to live on floodplains.[46] Creating informal settlements on flood plains can increase the risk of flooding by reducing the permeability of the land and interrupting the path of surface runoff. When flooding events do occur more people's homes and livelihoods and damaged and physical and human waste is collected and pollutes the river systems.[47]

Climate change

According to the World Bank, Peru is one of the most vulnerable countries in the world to climate change impacts, with water resources being the principle climate risks faced.[48] Peru holds 70% of the tropical glaciers worldwide, yet total glacial area coverage has reduced by 43% since 1970.[49] The deglaciation process increases peak river flow and heightens the risk of flood events occurring. A study conducted by the Peruvian Meteorological Agency (SENAMHI) suggests that by 2030 rainfall could decreased by up to 20% in the Andes.[50] Predicted temperature increases with climate change will also increase evapotranspiration in coastal Peru, reducing surface water availability and groundwater recharge rates considerably. Deglaciation, coupled with increased temperatures and erratic precipitation, means that watersheds may lose their capacity to provide sufficient water to meet demand.

According to the La Libertad Climate Change Plan, climate change has been responsible for 1,639 hectares of lost crops, including potato, corn, rice, oca, olluco, and damage to 12 kilometres of irrigation canal and 15 reservoirs due to the occurrence of heavy rains, droughts, hailstorms, floods and landslides; referred to locally as huaycos.[51]

El Niño–Southern Oscillation (ENSO)

The El Niño – Southern Oscillation (ENSO) is a major climate disruption triggered by elevated sea-water temperatures that directly affect precipitation patterns. Five strong El Niño events have affected Peru within the last five decades (1972/1973, 1982/1983, 1997/1998, 2015/2016 and 2017).[52] During ENSO events the normal annual precipitation of around 25 mm precipitation can increase up to 1640 mm. During the 2015 - 2016 14-month El Niño, ocean temperatures in the central and eastern Pacific, were as high as 3°C above the average, making this event one of the most intense El Niño on record.[53]

During the 2017 El Niño, torrential rains hit La Libertad and the surrounding coastal Departments, triggering floods that affected 16,409 people and destroyed around 1,517 households in the Virú Province.[54] Severe flash flooding and high force winds caused landslides that resulted in more than 3,000 hectares of damaged crops in La Libertad and collective losses to the agricultural sector of US$ 380 million.[55] 400 meters of irrigation canals from the Chavimochic Project were also destroyed.[56]

While scientists expected the major El Niño of 2015–16, the 2017 coastal El Nino disaster was not foreseen.[57] As a result of climate change researchers expect El Niño events to become more frequent as warmer sea surface temperatures make it more likely for El Niño events to trigger.[58]

Irrigation demand

The Chavimochic Irrigation Project has been designed so that water supply can meet future demand driven by agricultural expansion. Under an estimated temperature rise of between 0.4 and 0.8 ºC for the period up until 2030, irrigation demands are predicted to increase by 6% annually for the Chavimochic service area. This is due to higher temperatures increasing evapotranspiration and higher seasonal variability in precipitation, which increases the occurrence of drought conditions.[59] Demand will be compounded by similar increased demand and competition from other water users.

As future demands increase, any irrigation projects built with straight channels will make communities more vulnerable to flash flooding as the meander of the river path is lost which naturally slows the flow of water.[60, 61] It is important that natural vegetation is also retained to provide important ecosystems services such as water retention and soil stability.

Deforestation of the upper catchment

Historically, areas of forest in the upper catchment have been deforestation for firewood extraction, wood for timber and the charcoal trade and to make space for urban sprawl, mining and industrial agriculture. These natural areas in the upper catchment are important for the interception of rainwater and seas mist, as well as providing protection against soil erosion. Deforestation exacerbates the consequences of flooding and landslides as the removal of natural vegetation increases surface run off, as well as reducing the ability of water to percolate into the aquifer and recharge ground waters.[62]

Water Pollution

Water quality is monitored in 98 of Peru's 159 hydrographic basins. Data published by the National Water Authority (Autoridad Nacional del Agua) in 2015 found that more than 40% of the basins monitored at that time did not meet national environmental quality standards. The main contributing factors were the lack of wastewater treatment, industrial and mining pollution, and the leaching of agrochemicals into water courses and aquifers.[63]

Water governance in Peru

The Water Resources Act (Ley de Recursos Hídricos) (2009) was enacted to regulate the use and integrated management of water resources.[64] The law shifted water resources management to one entity attached to the Ministry of Agriculture, called the National Water Authority (Autoridad Nacional del Agua – (ANA)). The functions of the ANA include:

- overseeing and managing natural water sources;
- granting, modifying and revoking water use rights;
- evaluating environmental instruments such as management plans;
- authorizing construction work in natural water sources; and
- authorizing the release or reuse of treated wastewater.[65]

Subnational jurisdictions are delineated by river basin. There are 14 Administrative Water Authorities (Autoridad Administrativa del Agua – AAA), one for each defined basin and 71 Local Water Authorities (Autoridad Local del Agua – ALA) to support the corresponding AAA within each sub-watershed. The AAA and ALA work directly under the authority and funding of the ANA. The jurisdictions of regional governments do not always coincide with those corresponding to the hydrographic units of the administrative authorities and local administrations.[66]

The Water Resources Act also provided for the creation of the National System of Water Resource Management (SNGRH), with responsibility for integrated management in each hydrographic basin. The ANA is the main authority of the SNGRH. The SNGRH in turn is part of the National Environmental Management System (Sistema Nacional de Gestión Ambiental – SNGA).

The National Service of Meteorology and Hydrology (Servicio Nacional de Meteorología e Hidrología – SENAHMI) provides data to the other governing bodies.

Existing Policies and Plans for Managing Water and Ecosystem Services

The policies and plans described below identify some of the main priorities for integrated management of water resources. Common themes and interventions include habitat restoration (e.g. reforestation or afforestation) along riverbanks and in upper catchments, sustainable irrigation management, employing technology and monitoring systems for adapting to and mitigating climate change, and maximising the delivery of ecosystem services such as water filtration and soil stabilisation.

Many of the plans and strategies highlighted have an implementation phase that concludes in 2020 or 2021. As updated versions are produced, it's an opportunity to consider how EO-based modelling can help inform policy and associated practice to meet environmental challenges Peru faces in respect to water management.

National

National Environmental Plan (2011-2021)[67]

- 50% of hydrographic basins are managed sustainably and watershed conservation is prioritised by 2021.
- 25% of agricultural areas under irrigation use sustainable irrigation systems and water availability is improved by 2021.

National Water Resources Policy and Strategy[68]

- Promotes the use of integrated management of water resources as a coordinated multisector approach to water use that supports human well-being without compromising ecosystem sustainability.

National Water Resources Plan (2015-2035)[69]

- Initiate a program that will reforest the upper catchment to counteract the effects of deforestation, restore forest ecosystems and increase forest cover in order to increase the availability of water in hydrographic basins and decrease the contribution sediment in water catchments. The aim by 2035 is to reforest 454,000 hectares.

Multiannual Sector Strategic Plan - Agriculture (2015 - 2021)[70]

- By 2021 the protection of natural resources for agricultural development continues to be a priority for the country, establishing measures to counteract the accelerated degradation of agricultural soils and forests.
- Actions are prioritised that minimise agricultural vulnerability to the impact of climate change, through the construction of riparian defences and containment dikes in the rivers of the coast with history of overflow.
- In 2015, actions are prioritised to reduce soil erosion and recover the arable layer, which affects national agricultural production. This intervention was complemented with reforestation actions and sowing grasslands in the high Andean areas, in order to have a tree and herbaceous cover in the medium and long term that stabilises the soil, and reduces the surface runoff that causes soil erosion.

- Recognise that all agricultural activity is sustained by natural systems and requires maintenance and restoration of soil fertility, biological diversity and proper water management. Good agricultural practices exclude the use of synthetic agrochemicals, whose toxic effects affect human health and causes deterioration of the environment.

Regional

La Libertad Action Plan 2018-2020[71]
- Develop an application that allows citizens to learn more about the quality of the water that they are provided, and to publicly report the problems they encounter.

Regional Strategy for the Management of Water Resources in La Libertad 2011-2016[72]
- Involve the private sector in the integrated management of water resources.
- Implement conservation measures in upper watersheds to improve water quality and availability downstream.
- Anticipate risks and mitigate the impacts of extremes events such as droughts, floods and social conflicts by implementing continuous real-time monitoring of natural phenomena such as rainfall and runoff.
- Reforestation of areas considered at high risk of flooding and collapse, leading to landslides.
- Increase cultural recognition of water and raise awareness of the economic value of water resources.

The Environmental Action Plan 2013-2021 for the La Libertad Region[73]
- 50% of watersheds sustainably manage water resources and prioritise basin conservation by 2021.
- 25% of agricultural areas under irrigation use sustainable irrigation systems and improve the availability of water by 2021.
- By 2021 achieve 100% reduction in the average annual rate of deforestation for the period 2000 - 2017.
- 100% of priority areas promote afforestation and reforestation at the regional level improve the provision of ecosystem services by 2021.
- Areas effected by drought has been reduced by 20% by 2021.

La Libertad Regional Strategy for Climate Change 2016 – 2021[74]
- Improve rainwater storage and capture service in the headwaters basins and sub-basins to mitigate the impacts and adverse effects of change climate.
- Recover and sustainably manage degraded soils, agricultural ecosystems, grasslands and forestry.
- Increase capacity building and provide technical assistance on information and appropriate technology for adaptation to climate change in crops sensitive to climate change.
- Create an information service on new varieties of crops tolerant to droughts, temperature variations and precipitation and resistant to diseases and pests.

La Libertad Regional Reforestation Plan 2012 – 2021[75]
- Promote the reforestation of hydrographic basins and sustainable management of natural resources in order to: increase water capture and aquifer recharge within the hydrographic basin; reduce soil erosion; and improvement the quality of life of local communities.

La Libertad Regional Development Plan 2016-2021[76]
- Initiate a regional program for afforestation, reforestation and watershed management including a reforestation project in the Virú province.

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