Topic B2 - This presentation describe the potential and vulnerability of mangrove forests for adaptation.
This topic explores climate change issues in mangrove socio-ecological systems, meaning that we will be discussing both components of the system: (i) the ecological component which is the ecosystem itself and (ii) the human component which are the societies influencing and/or depending on the ecosystem. The interactions between the two components are also explored.
The main climate change related stressors that impact mangrove ecosystems are sea-level rise, hurricanes and storms, and changes in precipitation, especially in relation to decreases in rainfall.

But mangroves are also impacted by human-related stressors such as pollution, land-use conversion and over-harvesting, and increases in sedimentation. Frequently, it is the human stressors that induce and increase the vulnerability of mangroves to climate stressors, resulting in compound effects, as we will discuss in the next slides.
Sea-level rise is considered to be the biggest threat to mangrove ecosystems when the rate of mangrove sediment accretion and elevation is exceeded by the rate of relative sea-level change. Relative sea-level change is the observed change in water level at a particular point, relative to the level of the nearby land. Sea-level rise induces erosion and weakening of root structures, increased salinity, and too high duration, frequency and depth of mangrove inundation which can go beyond mangrove tolerance levels.

If sea level rises relative to the mangroves’ sediment surface, the mangroves are pressed to retreat landward so that they can maintain their preferred hydropersons (i.e. period, frequency and depth of inundation) and salinity. But the success of the mangroves’ landward migration will depend on various conditions such as the ability of individual species to colonize new habitats at required rates (relative to sea-level rise), the presence of barriers (mostly man-made such as seawalls, shoreline structures and roads) and the slope of the adjacent land.

Mangroves in environments characterized by sediment deficits (e.g. in low relief islands with a very limited number of rivers), low ground water tables, and erosion are thought to be the most sensitive to sea-level rise. However, various surface and subsurface processes control the rate of mangrove sediment surface elevation, and thus their ability to accommodate sea-level rise, but these processes are poorly understood.
In summary, mangrove vulnerability and resilience to sea-level rise largely depends on mangrove sediment surfaces, species composition and ability of different species to colonize new habitats, the slope of the adjacent land relative to that of the land that the mangroves currently occupy and the presence of obstacles that can impede landward migration, and the effects of other stressors.
Hurricanes and storms impact mangroves as they induce larger and more intense waves, increases in wind speed, sediment burial, and changes in water levels. Direct impacts include defoliation, uprooting and mortality. Tidal surges, coastal flooding and strong wave currents due to hurricanes and storms also impact sediment elevation through soil erosion or compression, and soil deposition.

Indirect impacts can be caused by effects in adjacent ecosystems or areas. Intense and long rain events upstream can lead to upland flooding causing erosion and debris flow to accumulate downstream in the habitat of mangroves.

These direct and indirect impacts can lead to changes in ecosystem structure and composition, species diversity, succession processes, nutrient cycling and plant and animal interactions.

In the case of tree mortality, recovery through seedling recruitment might not occur if changes in sediment elevation and hydrology have been induced by storms and other stressors. The effects of storms on mangrove sediment (i.e. decreases in sediment – don’t quite understand, explain further) can also increase the vulnerability of the ecosystem to sea-level rise.
Changes in precipitation are expected to affect mangrove growth and distribution. Increases in precipitation will impact mangroves positively while decreases will have a negative impact. **Depends on what sea level is doing**

Increases in rainfall will lead to mangrove area expansion, as mangroves will be able to colonize previously unvegetated areas of landward fringes in tidal wetlands. **Is it the freshwater input that limits mangrove expansion?** Areas with higher rainfall have also been shown to have higher mangrove diversity and productivity in comparison to areas with less rainfall, due to the higher supply of fluvial sediment and nutrients and reduced exposure to salinity and sulfate. With increased freshwater inputs, mangroves are also likely to increase **carbon accumulation.**

On the other hand, decreases in rainfall and increases in evaporation will lead to increases in salinity due to lower groundwater tables and less surface freshwater input in to the mangrove ecosystem. This will lead to net losses of peat, as increases in seawater sulfate augment the anaerobic decomposition of peat. This effect will increase mangrove vulnerability to relative sea-level rise even further. Increases in soil salinity will also decrease net primary productivity and growth, as mangroves will experience increased tissue salt levels. Seedling survival will also be compromised, resulting in changes in competition between mangrove species. It is highly likely that biodiversity
will decrease drastically. Mangrove areas will also decrease as landward areas and tidal zones will be converted to hypersaline flats.
In most cases, it is the anthropogenic stressors that pose the biggest threat to mangrove ecosystems. Man-made disturbances such as pollution, deforestation and degradation, debris flow and sediment deposition from the uplands due to land-use conversion upstream and flooding, etc., render mangrove ecosystems more vulnerable to climate pressures.

Although mangrove ecosystems provide pollution processing services, i.e. create a suitable environment for removing and transforming pollutants, excessive deposition of pollutants from sewage systems, industry and oil spills can negatively affect mangroves. Excessive concentration of pollutants affect mangroves as they are transferred through the roots of the trees. Sewage spills for example have high concentrations of organic and inorganic compounds, nutrient concentrations, heavy metals and faecal coliform counts, which lead to stunted mangrove growth and low pneumatophore density. The mortality of pneumatophores decreases aeration which affects the respiration rate of the root system, nutrient uptake and plant growth, and ultimately affects growth retardation.

With regards to sedimentation, although mangroves flourish on sedimentary shorelines, the excess input of sediment can cause reduced productivity and even mortality due to root smothering (i.e. sediment burial of roots). Excessive sedimentation can commonly occur from river floods for example, which in turn result from deforestation, river siltation and poor waste management in the uplands.

The impacts of deforestation and land-use conversion in mangroves are quite direct.
Apart from the reduction of tree cover and biodiversity, deforestation also modifies soils and has been linked to changes in bacterial diversity and nutrient dynamics. Sediments of deforested areas contain fewer dominant bacterial species and thus less functional pathways for microbial nutrient cycling. Logging in mangrove ecosystems also affects the microclimate causing increases in temperature (in both soil and air) and thus increasing evapotranspiration which is linked to increases in salinity.

As for land conversion (for agriculture, shrimp farming or settlements and industry), it can completely alter the hydrology of coastal wetlands due to changes in drainage and other modifications. When the hydrological conditions are altered, reforestation or restoration activities are most likely to fail in the future. The regeneration of mangroves after man-made deforestation is much slower than regeneration after natural deforestation from hurricanes for example.

Deforested or polluted mangrove areas also show slower sediment accretion rendering them more vulnerable to sea-level rise and other climate change related pressures.
The majority of the adaptation options for mangrove ecosystems that have been discussed in literature aim at reducing current anthropogenic pressures that are considered underlying causes of vulnerability, and enhancing ecosystem resilience.

Eliminating non-climate stresses on mangroves (e.g., deforestation, conversion for aquaculture, pollution) to increase overall ecosystem health and resilience, will decrease vulnerability to climate change. These ‘no regret’ options are justified and beneficial even in the absence of climate change pressures as they will enhance the delivery of beneficial mangrove ecosystem services to people as we will discuss in the next slides.

To enhance resilience to sea-level rise, activities within a mangrove catchment can be conducted to minimize long-term reductions in sediment or enhance elevation. These can include, for example, limiting the development of impervious surfaces within the mangrove catchment and managing rates and locations of groundwater extraction. Such activities can reduce alterations to natural groundwater recharge which influences mangrove elevation. Limiting human activities that reduce mangrove soil organic matter accumulation, such as deforestation and pollution inputs, can contribute to maintaining relatively natural controls on trends in sediment elevation. Depending on the tree species and nutrient added, nutrient enrichment can also have a positive effect. Enhancement of mangrove sediment accretion rates, such as through the beneficial use of dredge spoils, could also augment mangrove sediment elevation but excessive or sudden sediment depositions should be avoided.

Apart from management activities at the catchment area, ridge-to-reef management needs to be employed as well, to limit excessive sedimentation and pollution inflow from the uplands. Ride-to-reef management is a holistic conservation and management approach that links conservation actions across the land and coast, from forested watersheds and ridges upstream, to rivers and estuaries, and further downstream to coastal ecosystems such as mangroves.

Proactive coastal landscape planning may facilitate long-term landward retreat of both ecosystems and settlements to accommodate future relative sea-level rise. ‘Managed retreat’ involves implementing land-use planning mechanisms before the effects of rising sea-level become apparent. Coastal development could continue until the eroding coastline becomes a safety hazard or begins to prevent landward migration of mangroves, at which time development could also retreat inland. Zoning rules for building setbacks can be used to reserve zones behind current mangroves for future mangrove habitat. Structures impeding mangrove migration could be removed or redesigned, and laws and rules could regulate the construction of new infrastructure based on erosion rates, selected setbacks,
Protected areas can be established and managed to maintain mangrove representation, replication and refugia. Ensuring representation of all mangrove community types in a protected area network and replication of identical communities to spread risk can increase the chances of mangrove ecosystems surviving climate change and other stressors. Protected area selection can include mangrove areas that act as climate change refugia, which means selecting communities that are likely to be more resilient to climate hazards, such as mature mangrove communities. Protecting refugia areas that resist and/or recover quickly from disturbance can serve as a source of recruits to re-colonize areas that are lost or damaged. Protected area networks should also account for likely movements of habitat boundaries and species ranges over time under different climate change scenarios, and also consider the role of ecosystems in the adaptation of society (as we will discuss in the following slides). Facilitated landward migration of mangrove may be necessary, as discussed in the previous point, and the connectivity between coastal ecosystems, including mangroves, should be protected to enhance overall resilience and maintain functional links.

Finally, mangrove restoration in areas where mangrove habitats previously existed can offset losses by climate change and consistent monitoring activities could help assess gradual changes. Regional networks using standardized techniques will enable the separation of site-based influences from global changes for a better understanding of mangrove responses to different stressors and enhance overall adaptive capacity in coastal socio-ecological systems.
The most important climate change pressures affecting people living in coastal areas are similar to the ones affecting mangrove ecosystems as seen in the previous slides. Sea-level rise, coastal storms and changes in precipitation impact settlements, economic sectors, livelihoods, health, and well-being. But local communities and economic sectors are also negatively impacted by changes in the ecosystems, which in turn affect the flow of ecosystem services that societies depend on. This renders coastal societies even more vulnerable to climate hazards and change.
Sea-level rise will impact people and economic sectors both directly and indirectly, especially in low-lying areas. Land loss and inundation due to rising sea waters will force the shoreline to recede and will decrease the land available for settlements, economic activities such as tourism, agriculture and livelihoods. Sea-level rise will also enhance coastal erosion which is already a big issue in many low-lying areas. Salinity intrusion will decrease agricultural production by decreasing fresh water content in the soils. Salinity intrusion affects soil nutrient availability and salt-sensitive crop productivity. Sea level rise will also increase the risk of coastal flooding, especially in combination with stronger tides, storms and precipitation. Commercial and subsistence fish populations will also be impacted, resulting in less income and food security for fisher folk.

All the aforementioned will force people to migrate landwards or elsewhere, which could entice conflicts and further resource degradation. Decreasing agricultural and fishery productivity will decrease food security, while more frequent and intense incidences of coastal flooding could lead to increased rates of malaria, and skin and gastrointestinal diseases. Losses and damages predicted to occur in infrastructure and ecosystems will likely lead to negative impacts on people and economic sectors.
Losses of life and property, including houses and livestock, and damages to infrastructure are the most striking direct impacts of coastal storms and the resulting floods and landslides. However, immediate and more long-term losses in agricultural yields constitute additional severe impacts that are followed by a range of other consequences. Storms not only disrupt current harvests but also potential future ones, for example, they disrupt the ability of rice seedlings to germinate. Aquaculture, e.g. fish and shrimp ponds, is also severely disrupted.

Coastal storms and floods affect access to food and drinking water, and increase the transmission risks of infectious diseases, such as diarrhea, hepatitis, malaria, dengue, pneumonia, eye infections and skin diseases. Because of damage to infrastructure, industry and settlements, larger loads of contaminants are released in the environment, further aggravating health risks. Due to all these impacts, including losses of valuable ecosystem services, populations are displaced and tourism activities are halted, with direct consequences to livelihoods, well-being and increased vulnerability to current and future hazards.
Increases or decreases in rainfall also impact coastal communities and economic sectors. The negative impacts of increases of precipitation are mostly related to intense rainfall events that lead to floods with the impacts described in the previous slide.

However, decreases in precipitation will aggrevate the already existing problems of fresh water scarcity that many coastal communities face. As already mentioned referencing the impacts on mangroves, less rainfall will translate to more soil water salinity negatively impacting agricultural yields and mangrove ecosystems.
The vulnerability of both ecosystems and societies is interlinked. As mentioned previously, if ecosystems are vulnerable they will be impacted by stressors which will hinder the provision of ecosystem services such as flood regulation, timber, etc. As people depend on ecosystem services for subsistence, livelihoods, safety from disasters, culture and recreation, and overall well-being, losses in ecosystem services will render people more vulnerable to a whole range of stressors, including climate change. Consequent impacts on socio-economic systems could force people towards unsustainable ecosystem management because of population displacement, losses in agriculture, conflicts etc. The unsustainable management of ecosystems increases their vulnerability. This is a vicious circle that can be reversed with sustainable and adaptive ecosystem management and ecosystem-based adaptation.
As discussed in topic B1, ecosystem-based adaptation refers to the use of ecosystem services to help people adapt to climate change. Mangrove ecosystems provide a wealth of services to people that enhance their adaptive capacity to climate change and other stressors. Mangroves protect coastal zones from tropical storms, sea-level rise, floods and erosion due to their ability to absorb and dissipate wave energy, increase carbon accumulation and stabilize coastal land.

Coastal communities protected by mangroves generally suffer less losses of life and property from hurricanes and coastal storms in comparison to settlements unprotected by mangroves. Planting mangroves on the seaward side of sea dykes and other infrastructure also reduces the costs of maintaining these defenses, as mangroves dissipate destructive wave energy, stabilize the sea floor and its slope, and trap sediment.

Due to their capacity to dissipate and absorb wave energy, mangroves also control erosion and other damages from sea-level rise. If the rates of mangrove sediment accretion and elevation are not compromised, mangroves can effectively accommodate sea-level rise and reduce the risks of coastal flooding, even in cases when they have to migrate landwards.

Mangrove ecosystems also provide a wealth of products on which communities depend for their subsistence and livelihoods. They are an important habitat for fish nurseries and thus have an influence on both coastal and pelagic fish populations. Furthermore, they regulate nutrient, water and sedimentation flows towards seagrasses and coral reefs providing services for these ecosystems as well. To people, they also provide products such as timber, honey, medicinal plants and other non-timber forest products.

However, ecosystem-based adaptation with mangrove ecosystem services is not a panacea and additional measures might need to be employed to assist socio-economic systems such as early warning systems for storms and infrastructure measures when the level of protection from mangroves ecosystems alone is not enough.
But, to ensure that mangrove ecosystems will be able to provide services for the adaptation of society, their vulnerability to climate change and other pressures needs to be assisted through restoration, sustainable management and the adaptation measures discussed in part 1.
Which drivers of change (climatic, anthropogenic) are the most important in the mangrove socio-ecological systems you are familiar with?

What interactions between drivers?

What is the potential and challenges of using mangrove ecosystem services for the adaptation of people in the areas you work in?
References


References


References


References


The Sustainable Wetlands Adaptation and Mitigation Program (SWAMP) is a collaborative effort by CIFOR, the USAID Forest Service, and the Dragon State University with support from USAID.

How to cite this file

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