ROLE OF HIGH SALINITY IN BLUE CARBON ECOSYSTEMS

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Blue carbon ecosystems (BCEs) are hypersaline ecosystems with high productivity, thus are of major global importance for CO₂ sequestration and accumulation of organic matter in the soil.

BCEs also hold tremendous potential for production of biomass for food, feed, fiber, fuel, and other economic purposes.

COASTAL AND MARINE ECOSYSTEMS such as mangrove forests, seagrass meadows and tidal marshes capture and store a huge amount of carbon - called ‘BLUE CARBON’
- Carbon sequestered by the ocean represents 55% of the ‘global carbon’
- Coastal habitats represent < 2% of ocean coverage but account for 50% of the carbon stored in oceanic sediments
- Per unit area C sequestration rate of mangrove forests, seagrass meadows, and tidal marshes is substantially greater than that of terrestrial forest soils.
- Plays a Crucial role in mitigating climate change

**CRITICAL STORAGE**

<table>
<thead>
<tr>
<th>Ocean + Coastal Habitats</th>
<th>83%</th>
<th>2%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global Carbon</td>
<td>83% of the global carbon cycle is circulated through the ocean.</td>
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<tr>
<td>Coastal Habitat Coverage</td>
<td>Coastal habitats cover less than 2% of the total ocean area.</td>
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<tr>
<td>Sediment Carbon</td>
<td>Coastal habitats account for approximately half of the total carbon sequestered in ocean sediments.</td>
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</table>

**Carbon Burial Rate (Mg C ha⁻¹ yr⁻¹)**

- Terrestrial
- Temperate: 0.051
- Tropical: 0.04
- Boreal: 0.046
- Mangrove: 2.26
- Seagrass: 1.38
- Salt marshes: 2.18

Mcleod et al., 2011

The Blue Carbon Initiative
Types of blue carbon ecosystems

Major BCEs are:

• Mangrove Forests
• Tidal Marshes
• Seagrass Meadows
• Algae
Mangroves

• Mangroves are a type of tropical forests at the edge of land and sea that flooded regularly by tidal water

• Among most carbon-rich forests in tropics

• Average annual C sequestration is **6 – 8 Mg CO$_2$e/ha** (mega grams (Mg) carbon dioxide equivalents per hectare) – these rates are 2 - 4 times greater than global rates observed in mature tropical forests

• Mangroves provide ~ US $1.6 billion each year in ecosystem services i.e. supporting fisheries, filtering pollutants and contaminants, improve marine water quality, and protect coastal developments and communities against storms, flood and erosion

• In last 50 years – 30-50% mangroves have been lost globally and continue to be lost at a rate of 2% each year

• Major causes of destructions are:
  - Deforestation
  - Aquaculture
  - Unsustainable coastal development

• Although mangroves account only 0.7% of the tropical forest area but the C emissions due to the degradation of mangroves can be as high as 10% of the total emissions from global deforestation.
Ecosystem C stocks

Donato et al., 2011
**Tidal Marshes**

- Tidal marshes are coastal wetlands with deep soil - built through the accumulation of mineral sediments and organic materials, flooded with salty water brought in by tides
- Marshes also serve as important Carbon sinks
- Almost all carbon in tidal marsh ecosystems is found in the soil, which can be several meters deep
- Marshes sequester C in underground biomass due to high rates of *organic sediments* and *anaerobic-dominated decomposition*
- Salt marshes covers ~22,000 – 400,000 Km² Yr⁻¹ globally with a Carbon burial rate of 6 – 8 Mg CO₂e/ha
- These rates are about 2 – 4 times greater than those observed in mature tropical forests
- Tidal marshes filters pollutants, maintain the marine water quality, serve as a buffer to coastal communities by absorbing energy from storms and floods, prevent soil erosion
- Tidal and freshwater marshes are being lost at a rate of 1-2% per year
- Major threats are – draining for coastal development, conversion to agriculture and rising sea levels
Seagrasses

• Seagrasses are submerged flowering plants with deep roots – found in Meadows along the shores

• Serve as important Carbon sinks – **Organic C** Pool of the **Global seagrass ecosystem** could be as high as **19.9 billion metric tons**

• Carbon accumulates in seagrass ecosystems and is found in the soil, which can be up to 4 meters deep

• Average Carbon burial rate is ~ **138 g C m\(^{-2}\) Yr\(^{-1}\)**

• Although seagrasses account for less than **0.2 %** of the world’s oceans they sequester ~ **10%** of the C buried in oceans annually (**27.4Tg C Yr\(^{-1}\)**)

• Seagrasses can store up to twice as much C than terrestrial forests

• Tidal and freshwater marshes are being lost at a rate of 1-2% per year

• Major threats are – draining for coastal development, conversion to agriculture and rising sea levels

https://ocean.si.edu/ocean-life/
Algae

- Both macro and microalgae play a vital role in carbon sequestration
- Algae has been proposed as a short-term Carbon storage pool that can be used as a feedstock for the production of various biogenic fuels
- Many cyanobacteria, micro and macroalgae utilize carbonate as a carbon source for photosynthesis
- In South Korea, macroalgae have been utilized as a part of a climate change mitigation program – they have established the Coastal CO2 removal Belt, which is composed of artificial and natural ecosystems – the goal is to capture carbon by using large areas of Kelp Forest
- Major threats are – draining for coastal development, conversion to agriculture and rising sea levels
Significance of Blue Carbon Ecosystems in Tackling Climate Change

- When protected or restored - **Blue carbon ecosystems** sequester and store carbon.
- When degraded or destroyed - these ecosystems emit carbon they have stored for centuries into the atmosphere and oceans - become sources of greenhouse gases.
- Experts estimate that as much as **1.02 billion tons** of CO₂ are being released annually from degraded coastal ecosystems, which is equivalent to 19% of emissions from tropical deforestation globally.
- Mangroves, tidal marshes and seagrasses are critical along the world's coasts, supporting coastal water quality, healthy fisheries, and coastal protection against floods and storms.
- Mangroves are estimated to be worth at least **US $1.6 billion each year** in ecosystem services that support coastal livelihoods and human populations around the world.
Protecting and restoring blue carbon ecosystems is critical for climate change mitigation - offering up to 14% of the mitigation potential from ocean climate action required to keep global temperature rise within 2°C above pre-industrial levels.

- BCEs mitigate climate change by sequestering CO₂ from the atmosphere and oceans at significantly higher rates, per unit area, than terrestrial forests.
- Carbon deposits accumulated within these systems are stored in the form of aboveground biomass (tree trunks, stems and leaves), belowground biomass (roots and rhizomes) and in C-rich organic soils typical to these ecosystems.

- **Seagrass** ~ 500 t CO₂e/ha,
- **Estuarine mangroves** ~ 1,060 t CO₂e/ha and
- **Oceanic mangroves** ~ 1,800 t CO₂e/ha
Compared to other ecosystems, blue carbon ecosystems release significant amount of CO2 per unit area upon conversion or degradation.

- Global losses in the extent of the coastal ecosystem are estimated at between 25% and 50%.
- Current rates of losses may result in 0.5 – 1.02 billion tons of CO2 released annually.
- Although the global area of mangroves, salt marshes and seagrass meadows is only 2-6% of the total area of the tropical forest the degradation of these ecosystems accounts for 3-19% of C emissions from global deforestation.

**Main Drivers for the conversion and degradation:**

1. Aquaculture
2. Agriculture
3. Mangrove forest exploitation
4. Pollution
5. Industrial and urban developments
6. Raising sea levels
Impact of Salinity on Blue Carbon Ecosystems

• On the global scale, coherent trends of salinity have been observed and are characterized by global freshening in sub-polar latitudes and a salinification of the shallower parts of the tropical and subtropical oceans

• **Salinity** of coastal waters is strongly influenced by rainfall and river flows – thus, seagrasses and seaweeds, which have varying tolerances of low salinity, are also influenced by variation in rainfall, river, and **groundwater** flows, which may affect their diversity, abundance, productivity and thus contributions to carbon sequestration

• Because of the dependence of mangroves and saltmarshes on freshwater inputs, extreme drought can result in reduced productivity of mangrove and saltmarsh communities, high mortality rates – lower species diversity and abundance

• Increasing salinity due to climate change has changed the adaptability of certain mangrove species

• Severe environmental stress from temperature fluctuations, high soil salinity, and low oxygen availability has limited salt marsh plant diversity to a handful of stress-tolerant, halophytic genera
**Impact of Salinity on BCE: Mangrove forest of Pakistan (A Case Study)**

- **Dense mangrove forests** are present along the entire coastal regions of the Sindh province, especially in the vicinity of the **Indus delta**. Some populations are also found in a few places (like Miani Hor, Kalmat Khor and Gawader bay on the Balochistan coast)

- Mangrove populations are threatened – by over-exploitation, pollution, and a decline in fluvial discharge into the Indus delta.

- Decrease in fluvial discharge would result in increased salinity of seawater, which reportedly prevents fruiting, and causes senescence of immature flowers and buds.

- It is estimated that mangrove cover has **decreased by 15% in past 20 years** due to a reduction in Indus discharge.

- Earlier Indus deltic region had 8 Mangrove species but now only 4 left (most common species is **Avicennia marina** (95%))

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**Mangrove Species**

<table>
<thead>
<tr>
<th>Species</th>
<th>Status</th>
</tr>
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<tbody>
<tr>
<td>Avicennia marina</td>
<td>Present</td>
</tr>
<tr>
<td>Rhizophora mucronata</td>
<td>Present</td>
</tr>
<tr>
<td>Ceriops tagal</td>
<td>Present</td>
</tr>
<tr>
<td>Aegiceras corniculatum</td>
<td>Present</td>
</tr>
<tr>
<td>Ceriops roxburgiana</td>
<td>Extinct</td>
</tr>
<tr>
<td>Bruguiera conglobata</td>
<td>Extinct</td>
</tr>
<tr>
<td>Rhizophora apiculata</td>
<td>Extinct</td>
</tr>
<tr>
<td>Sonneratia caseolaris</td>
<td>Extinct</td>
</tr>
</tbody>
</table>

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**Distribution of Mangroves along the Sindh and Balochistan coast**

Rafique, 2018
• salinity raised the red alert over the degradation of water and soil properties, which influences the physiological behavior of the common mangrove species

• Most of the dominant mangroves and associated plant species suffer from ‘top dying’ disease due to increased salinity

• Studies have shown that high salinity in growth medium reduces growth of mangroves – *Avicennia*, *Rhizophora* and *Ceriops* had a significant reduction in growth at 100% seawater salinity (~600 mM NaCl)

• Future mangrove reforestation required mangrove seedlings - chosen based on their salinity tolerance
Blue Carbon Ecosystems: Need for Conservation

- Actions urgently required to prevent further degradation and loss of BCEs:
  1. Sustainable use of mangrove forests
  2. Restore hydrology
  3. Restore vegetation in degraded BCEs
  4. Reduce anthropogenic nutrients input
  5. Establish protected areas
  6. Sustainable management for Aquaculture and agriculture activities in the coastal regions (specially threatened/degraded areas e.g. Mangrove estuaries in Sindh coastal region, Pakistan)
  7. Planed and monitored coastal development projects

- In order to achieve, 17 United Nations Sustainability Goals, scientific research into BCEs is an absolutely important element
- Moreover, monitoring, restoration and conservation of the remaining blue carbon ecosystems are of utmost important in this regard
To provide comprehensive scientific documentation inspiring the way forward on how to sustainably utilize, conserve and restore blue carbon ecosystems in the best interest of humanity.

Blue Carbon Ecosystems for Sustainable Development
The editors of the book series are happy to generate with the volume editors and authors comprehensive and new scientific knowledge on Blue Carbon Ecosystems and their components, with a special view on halophytes and salinity.

This Blue Carbon Ecosystems for Sustainable Development series will have two major innovations:

a) The geographical realm is open for all global compartments beyond the sub-tropical and tropical regions that were previously covered.

b) The title of this new series clearly highlights the globally important issue of climate change and nature-based solutions of carbon sequestration in support of achieving the UN SDGs.
Blue Carbon Ecosystems for Sustainable Development

- At present 7 volumes are planned:

1. Blue Carbon Ecosystems in UN Conservation Sites: Definition, Conservation, Restoration --- **In Progress**
2. Blue Carbon Ecosystems contribution to End Hunger and Ensure Food Security: A resource for UN SDG-02 --- **In Progress**
3. Blue Carbon Ecosystems contribution to Combat Global Climate Change: A resource for UN SDG-13
4. Blue Carbon Ecosystems contributions to protect, restore and sustainably use terrestrial, coastal and marine ecosystems and fight land degradation: A resource for UN SDG-14, and 15
5. Blue Carbon Ecosystems: Biology and Innovations
6. Blue Carbon Ecosystems: Halophyte Science and Utilization
7. Blue Carbon Ecosystems for Sustainable Development
Indus Delta mangroves are among the top 10 mangrove forests in the world

Thank you