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Adaptation Strategies in Agriculture to Cope with Climate Change

Comparison between Bangladesh and Germany

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Structure

- Introduction to selected countries
- Characteristics of agricultural sectors
- Main impacts of climate change on crop production
- Adaptation strategies for selected impact
- Concluding assessment
- Discussion




How does agriculture look like in Germany?

Population: 83 million[1]
Size: 357.022 km^2 [2]
GDP: USD 3806 billion[3]
Temperate climate; “moderate” vulnerability of agriculture to climate change without adaptation measures.[4]

Agricultural land use[5]:
37% wheat
33% vegetables & other arable crops
28,5 % grassland
1,5 % fruits



[1] Worldbank, 2021 | [2] Statista, 2022 | [3] Worldbank, 2021 | [4] World Weather & Climate Information, 2022 | [5] Bundesinformationszentrum Landwirtschaft, 2021
Pictures: shutterstock.com, unsplash.com




How does agriculture look like in Bangladesh?

Population: 164.7 million[1]
Size: 148,460 km² [2]
GDP: USD 323 billion [3]
Tropical, Lower Riparian Country
World's Largest Delta- Ganges Delta [4]

Agricultural land use[5] :
72.2% Rice
24.1%Others (E.g. Wheat, Maize, Potato)
3.7% Fruits and Vegetables



[1]World Bank, 2020 | [2] The World Factbook, Updated- 22 March,2022 | [3] WorldBank, 2020 | [4] reliefweb.int, 2021 | [5] think-asia.org 2017
pictures: Pinterest.com, thedailystar.net, peakps.com, unsplash.com, create.vista.com

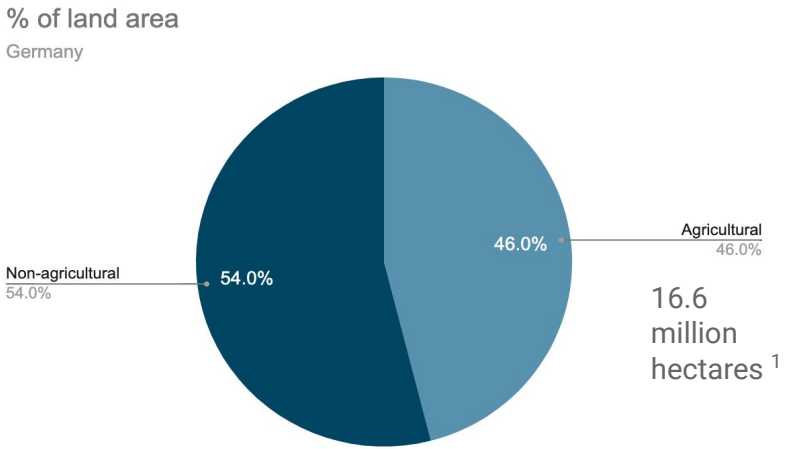
Characteristics of the Agricultural Sector

Economic and socioeconomic factors

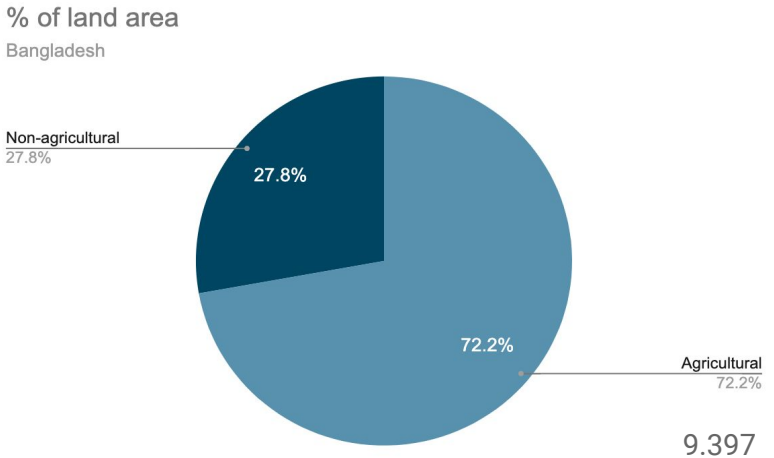
	Germany [1]	Bangladesh
Total agricultural production	60 billion $	40.899 billion $ (total market size of agricultural production and trade)[2]
Agriculture as percent of GDP	1.8%	12.92 % [3]
Total population in agricultural sector	937,000	26,000,000 [4]
% of population in agricultural sector	1.1%	42,7%[4]

[1] Statistisches Bundesamt, 2020, BMEL
[2] trade.gov, 2020
[3] Statista, 2020
[4] Preliminary Report on Agriculture Census, 2019

Scale factors



16.6 million hectares [1]



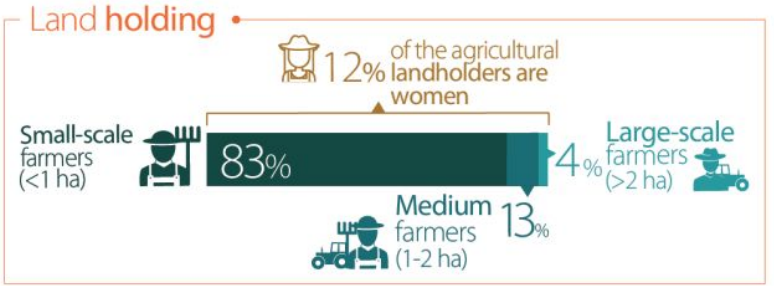
9.397 million hectares [2]

[1] BMEL (2020)
[2] FAOSTAT(2019)

Scale factors

	Germany	Bangladesh
Total cropland [million ha]	11.9 [1]	9.397[4]
Cropland area per capita (ha/capita)	0.14[2] (2018)	0.05 [5]
Average size of farms	60 ha [3]	83% farmers own less than 1 ha of land [6]

[1] BMEL (2020)
[2] FAO (2018)
[3] Heinrich Böll (2017)
[4] FAO (2019)
[5] FAO (2018)
[6] World Bank. (2017)

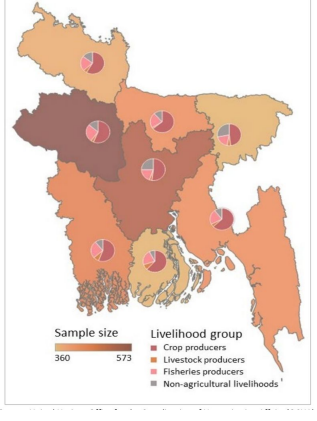


World Bank. (2017)

Scale factors

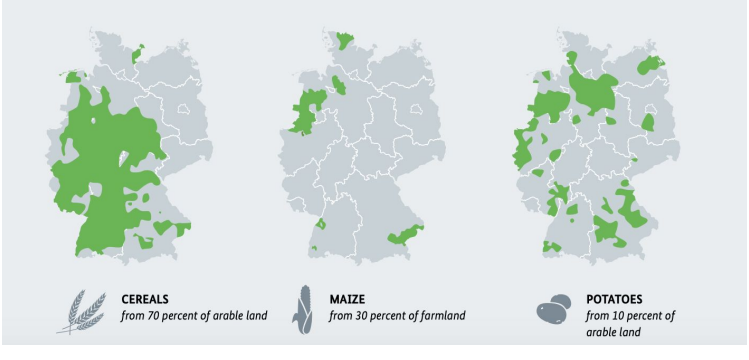
	Germany [1]	Bangladesh [2]
Main crops	Wheat, Potatoes, Maize	Rice, Wheat, Potatoes, Maize
Yield per hectare (quintals/ha)	Wheat: 73.0 Potatoes: 437.9 Silage maize: 472.3	Wheat: 30.97 Potatoes: 208.215 Maize: 85.123 Rice: 48.088

1 BMEL, 2020
2 FAO, 2020



FAO, 2020

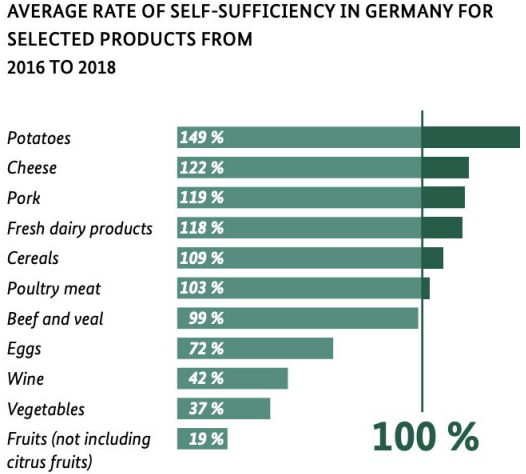
Heinrich Böll, 2017



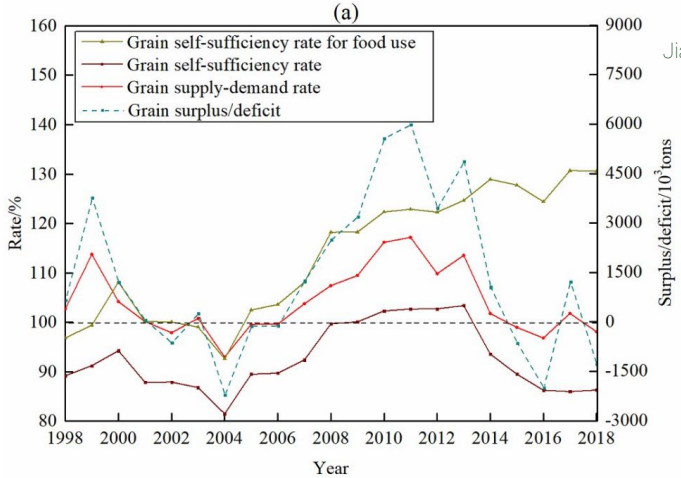
Scale factors

	Germany [1]	Bangladesh [2]
Biomass production (million tons)	264	58.81 (grain production)
Biomass export (million tons)	21	1.001 Million USD [3]
Biomass import (million tons)	42	8.05 (grain import)

1 DBV, Statistisches Bundesamt
2 Jian L. Et al (2021)
3 World Bank., 2017



BMEL (2020)



Jian L. Et al (2021)

Environmental impacts

	Germany	Bangladesh
Water used for irrigation	1.4% of 24 billion cubic meters of total available water. [1]	88% of total water withdrawn is agriculture water. [3]
Land use conversion activities	Arable land grew by 27 percent between 1990 and 2016, mainly by turning pasture into cropland. Around 66 ha are used to build new houses or roads in Germany every day. [2]	Land use conversion due to increased urban and peri-urban expansion. Arable land area is even decreasing over time due to increasing demand for residential and industrial use. [4]
Deforestation	Mainly due to impacts of climate change and pests.	Due to increasing population, agriculture and farming, urbanization [5]

1 BMEL (2020)
2 Umwelt Bundesamt (2021)
3 World Bank (2017)
4 J. Timsina et al. (2018)
5 Banglapedia (last update 2021)

Main Impacts of Climate Change and Their Relevance for Crop Production

Mentimeter

Based on your understanding, what could be the main impacts of climate change on the agricultural sector of Germany?

Based on your understanding, what could be the main impacts of climate change on the agricultural sector of Bangladesh?

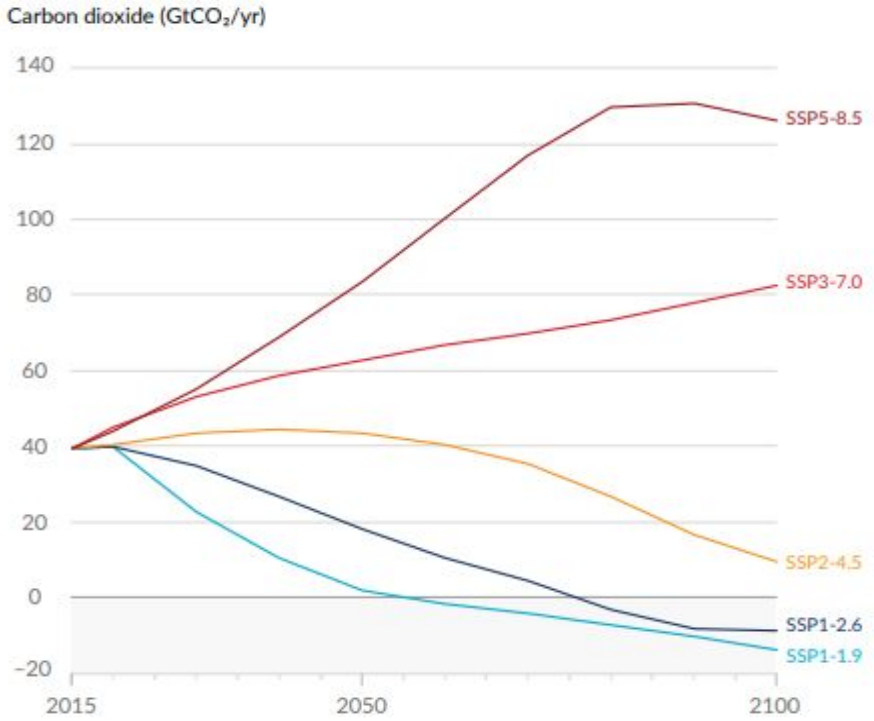
Germany

Main Impacts of Climate Change and Their Relevance for Crop Production

Temperature scenarios according to IPCC (2021)

Global surface temperature in 2081–2100 (compared to 1850–1900)

- Under the very low GHG emissions scenario: 1.0°C to 1.8°C
- Under the intermediate GHG emissions scenario: 2.1°C to 3.5°C
- Under the very high GHG emissions scenario: 3.3°C to 5.7°C



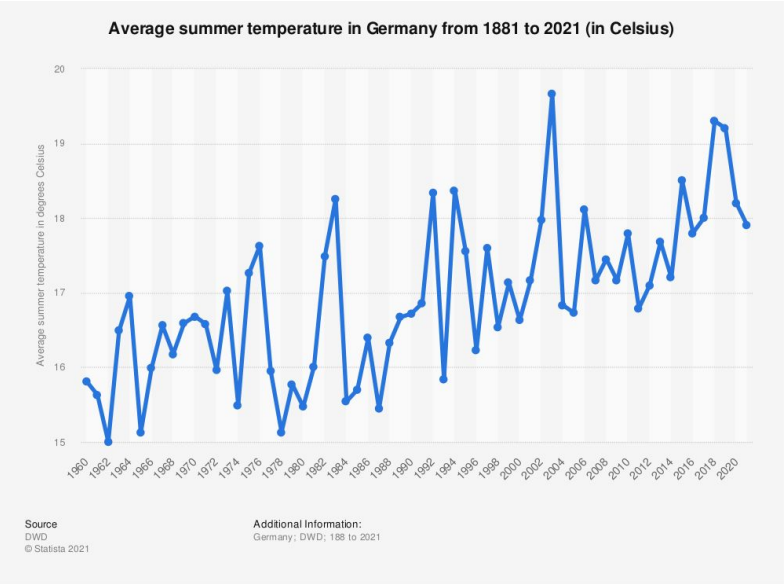
IPCC, 2021

Rising average temperatures

- Temperature in Germany about 1.5 degree Celsius warmer than 1881 (first weather recording)

Consequences:

- Risk of yield losses
- Warmer winter and later frosts
- Spread of plant diseases and pests
- Extended vegetation period, possibly increased yields
- Earlier start of growth period
- Higher probability of heat stresses in summer, thunderstorms and other extreme weather events



DWD, 2021

BMEL, 2020 | Umweltbundesamt, 2020

Increased heavy precipitation events

- Weather extremes will increase in the next three decades with high to very high probability[1]

Consequences:

- Increased surface runoff
  - Soil erosion
  - Accumulation of mud
  - Flood damage
- → Yield loss, especially strong effects in sensitive growth phases of plants (e.g. leaf formation)

Other extreme weather events

- (thunder-)/ storms
- hails

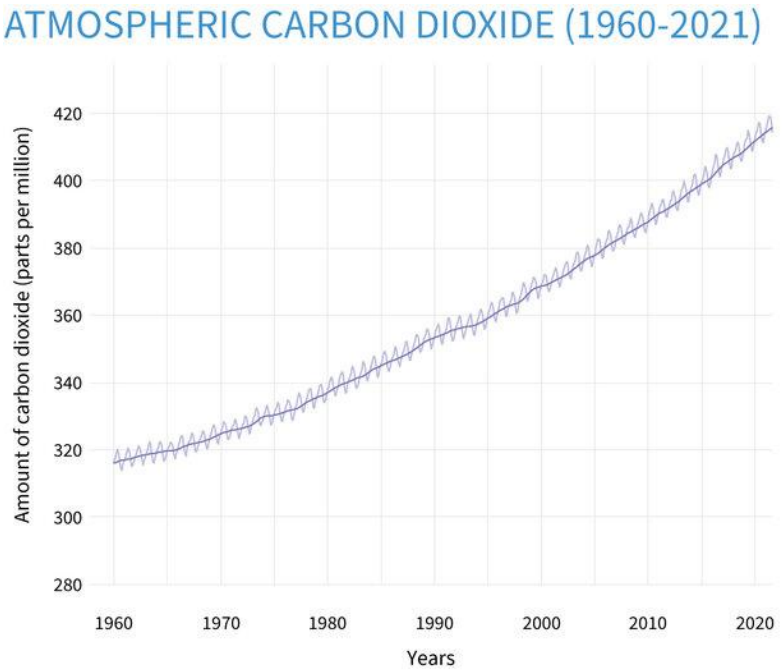
BLE, 2022 | [1]UBA,2020

Higher concentration of CO_2 ("CO_2 fertilization effect")

- CO_2 concentration is rising
- February 2021: 416.75 ppm[1]

Consequences:

- Could stimulate plant growth and photosynthesis
- However: often has no or only a temporary effect on growth as negative effects such as heat and drought predominate



[1]NoAA, 2022 | Umweltbundesamt, 2022

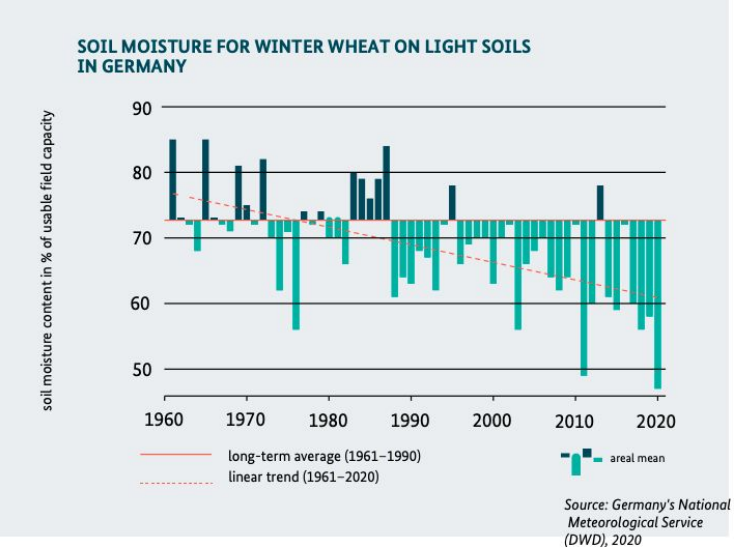
Lindsey, 2021

Droughts and decreased precipitation

- Increases in frequency, intensity and severity of droughts [1]
- Decreasing precipitation in spring and summer [2]
- 2018 and 2019 have been the driest years ever measured in Germany. [3]

Consequences:

- Significant regional crop loss
- Dry soils
- Less water and nutrients available for plants
- Closing of the stomata (no further photosynthesis)
- Increased risk of wildfires
- Increased need for irrigation



BMEL, 2020

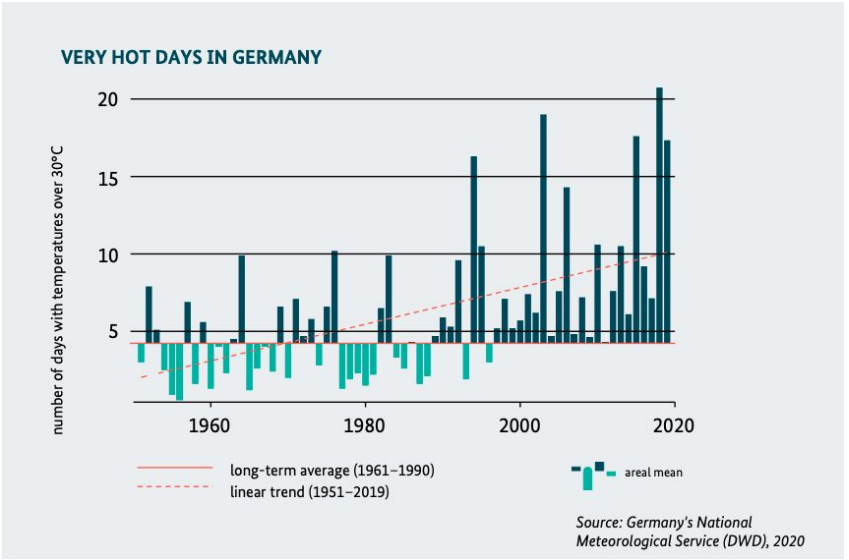
[1]IPCC, 2022 | [2]UBA, 2020 | [3]BMEL, 2020

Heat Wave

- Increases in frequency, intensity and severity of heatwaves [1]
- Twice as much hot days today compared to 1960-1980
- Ten hottest summers within the past 20 years [2]

Consequences

- Yield loss, especially during sensitive growth phases of plants
- Heat stress for plants

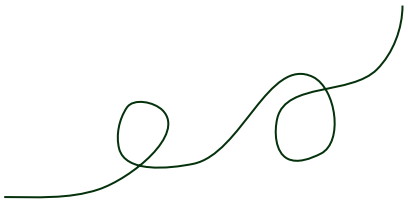


BMEL, 2020

[1]IPCC, 2022 | [2]BMEL, 2020

Adaptation Strategies

Germany



Adaptation Strategies

Stress: Extreme heats during summer months

Adaptation strategy: Heat tolerant crops

- **Stress**: Extreme heat during the vegetation period in the summer months

- **Practice**: Promote crops that are more heat tolerant and/or have the optimal heat range.[1]
  Definition Heat tolerance (HT): ability of the plant to grow and produce economic yield under high temperatures[2]:

  1. Change main crop
  -> e.g. grow soybeans in Germany

  2. Same crop
  -> Pick the right wheat breed: e.g. Durum wheat[3]
  -> Breeding new varieties[4], Breeder genotype provides certain advantages, takes time to implement them on the market, Research on new technologies in wheat breeding. Limitation on pesticides.

  Info: GMO crops are not allowed in Germany (present legislation)

[1]FAO (2021) | [2]Govindaraj (2018) | [3]deutschlandfunk.de (2019) | [4]spektrum.de (2018)

Photo:https://www.bild.de/regional/nuernberg/hitzewelle/hitze-bauern-schaeden-hilfe-soeder-kaniber-56579518.bild.html

Adaptation strategy: Heat tolerant crops

- Suitable for farmers?
  Business Cases “Change main crop”:

	Small-scale farmer	Big-scale farmer
New crop	Organic soybean	Soybean
Investment	Big for new machines	Big for new machines
Revenue	High	High
Timeframe	Longterm	Longterm
Sales	Self-marketing	Market
Risk	High risk during conversion	High risk if e.g. experiment on 30% of the fields then fails.

- Already implemented: Cultivation of soybeans has increased rapidly.[1]

1 oekolandbau.de, 2021

Photo by Mailson Pignata from Unsplash

Adaptation strategy: Heat tolerant crops

- **Investment**
  Short-term e.g. same crop, different breed
  Long-term e.g. new crop, investment in new machines

- **Potential**
  Achieve higher yield in areas where high temperatures are expected and ensure food production.
  e.g soybean: + Market need (main imported crop for animal feed) + crop rotation

- **Limitation**
  Extreme weather fluctuations
  -> hard to predict in which intensity heat waves will happen

FAO, 2021

Photo by fotocostic from Unsplash

Adaptation strategy: Irrigation

- addressing several climate change impacts
- development of more efficient, water-saving, data-based and site-optimised irrigation systems
- agricultural irrigation: 1,4 % of 24 billion m³ of Germany's fresh water[1] (particularly used in fruit growing[2])
- → **water as a scarce resource has to be used efficiently**[1], → (despite instant adaptation effects) just additional irrigation not that sustainable
- further adverse effects:
  - Lowering the groundwater level and changing the soil's mineral balance[2]
  - Little farms in Germany have irrigation measures (2%[4])
  - Most expensive of all yield-increasing and yield-securing farm inputs, yet can be cost-effective[3]
- long-term investment, governmental funding for resource-efficient systems available[2]

[1]BMEL, 2020 | [2]UBA,2019 | [3]Thünen Institut | [4]BIZL, 2022

Adaptation strategy: Irrigation

Drip irrigation:

- efficient water-use
- minimized evaporation
- reduced soil erosion and macronutrient losses
- promote weed control
- reduced risk of diseases
- **But**: additional work during cultivation and harvest → techniques are currently mostly conventional
- ↔ **sprinkler irrigation**
- stationary system (can't be moved to water different fields as with sprinklers)
- high investment, yet less water-usage

Programmed irrigation:

- efficient, adapted and intelligent use of water
- reduces losses from evaporation when watering in dusk/dawn

FAO, 2021 | Gendries, 2018

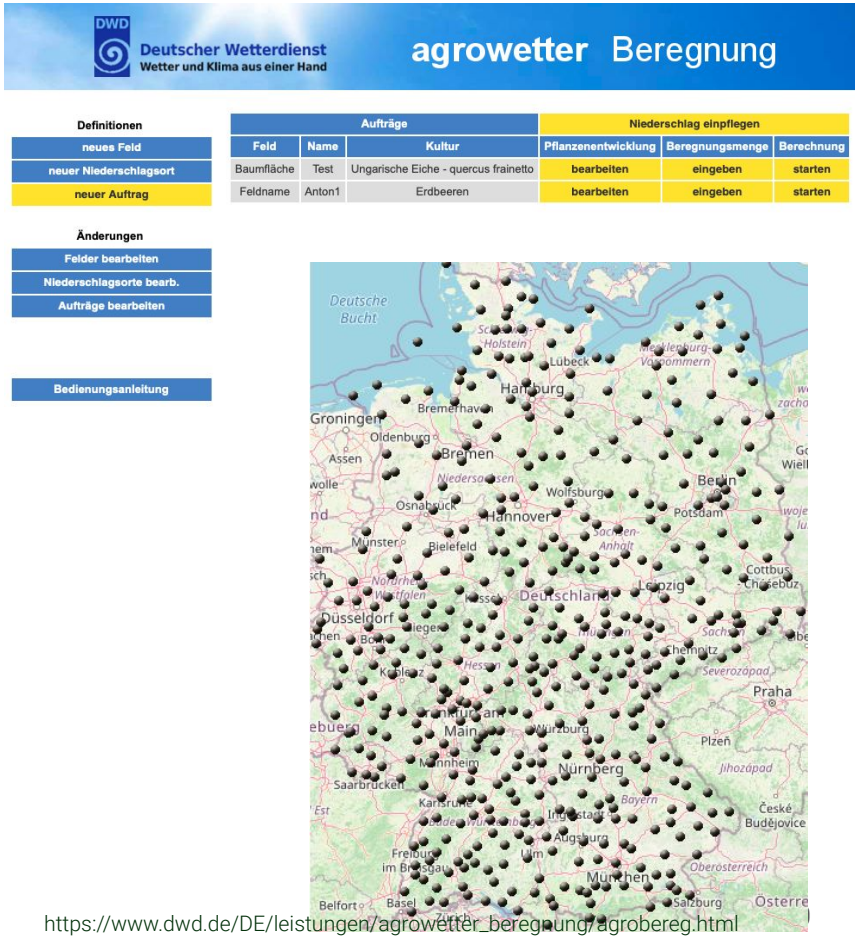
Photo by Przemyslaw Stroinski on Unsplash

Example: ‘Agrowetter Beregnung’

by the DWD (German Weather Service)

- interactive online advisory system for irrigation
- weather stations measure evaporation
- online advisory system accounts for precipitation and specific crop and soil characteristics of farmer
- → **calculates the prospected indiv. soil moisture course, recommending an optimal irrigation quantity** adapted to the conditions and eventual water shortages / heat waves

- Could be short- or long-term investment, low-priced (80 €/season) and easy to implement



https://www.dwd.de/DE/leistungen/agrowetter_beregnung/agrobereg.html

Adaptation Strategy: Agroforestry

What is Agroforestry?

The combination of agriculture and forest

Crops: grain, corn or sunflower

Trees: fruit or willow trees, trees for wood usage

Agfoward, 2022

Agroforestry: Advantages

… for heat events:

- Providing shade to sensitive crops
- Regulating a cooler environment
- Reducing soil temperature

… for agriculture in general:

- Improving nutrient cycling and availability
- Improving water efficiency
- Reducing wind erosion and soil loss

FAO, 2015

…other advantages:

- Ecosystem services
- Climate change mitigation and adaptation
- Protects soil, enhances biodiversity and improves overall condition of landscapes

⇨ *Sustainable strategy*

Agroforestry

What are main challenges for farmers?

- **long-term**: capital investment, binding to a specific area, growth time for trees
- high costs for implementation and management
- labor-intensive[1]
- more complex and knowledge intensive than conventional agriculture
- much less information on agroforestry than on other agricultural approaches
- greater administrative burden [2]

[1]BLE, 2022 | [2]EPRS, 2020

Agroforestry

What are necessary preconditions for a success?

- Farm level:
  - the used crops and trees need to be adapted to the local environment
  - not possible:
    - above the forest line
    - in very dry or very wet areas
  - the farmer is required to have skills in several areas of work
  - the farmer needs sufficient labor
  - there is the need for capital

Subsidies on a political level

[1]EPRS, 2020

Agroforestry: Implementation

- EU-level: supported through the Common agricultural policies (CAP)
- **Germany**'s' CAP Strategic Plan (2023-2027):
    - goal to implement 200.000 ha wooded area in agroforestry systems
    - founding: 60 Euro per hectare
    - criticized by the German association of agroforestry[2]
- **Brandenburg**: Project: “Ackerbau(m)” of the HNEE[3]

DEFAF, 2022

[1]EPRS, 2020 | [2]DEFAF, 2022 | [3]HNEE, 2022

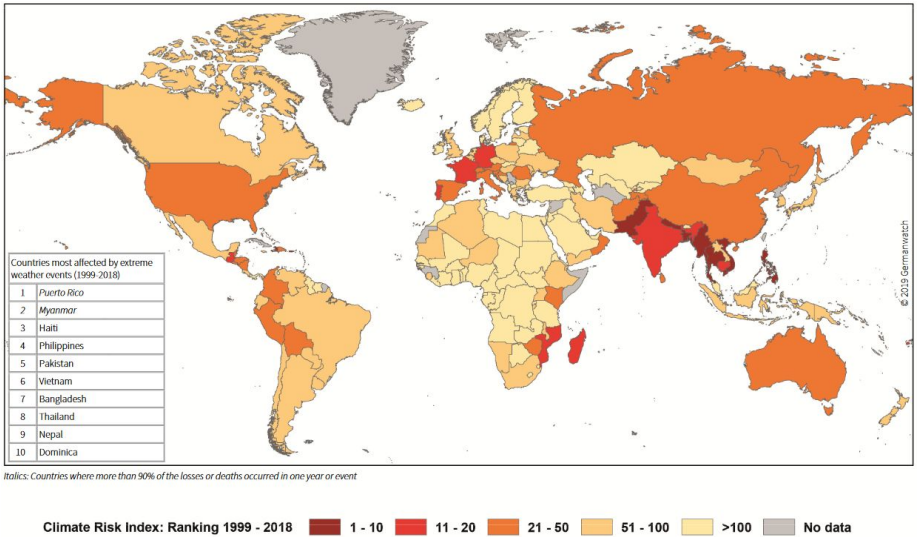
Main Impacts of Climate Change and Their Relevance for Crop Production

Bangladesh

Main Impacts of Climate Change and Their Relevance for Crop Production

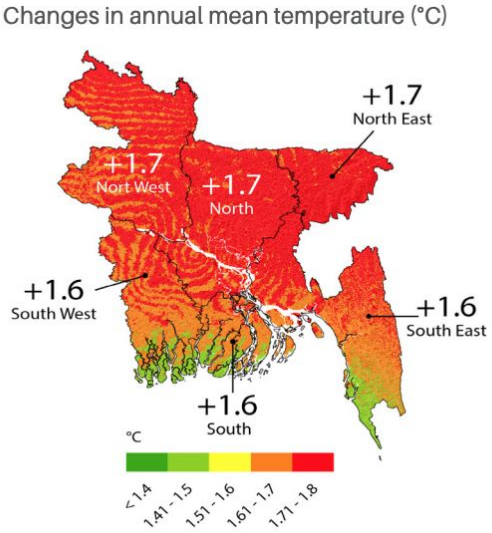
Climate Change

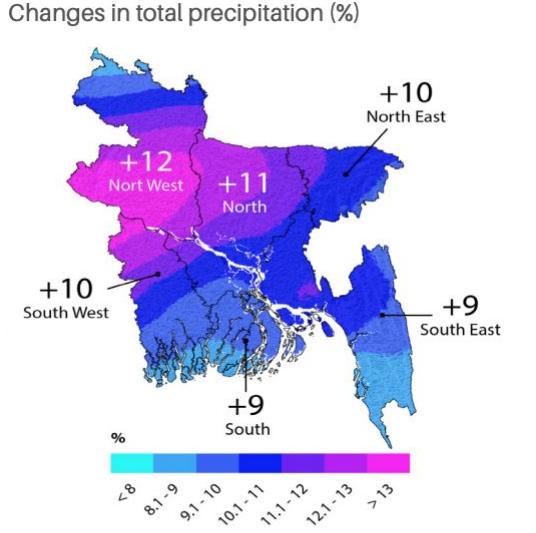
- One of the most affected countries
- Bangladesh lost 0,41% of its GDP from 2000 - 2019 because of climate change
- 6,5 million people have been displaced in Bangladesh
- Losses related to the 2007 and 2009 cyclones were estimated at around two million tons of rice, enough to feed 10 million people. (World Bank, 2017)
- Climate change
  - Sea level rise & cyclones
  - Drought
  - Riverbank erosion
  - Floods (due to sea level rise)
  - Change of temperatures and precipitation



Source: Climate Risk Index 2021

Change of temperatures and precipitation by 2050





(World Bank,2017)

Increase in floods

- Heavy rainfall (monsoon season)
- Melting Himalayan glaciers (feeding rivers around Bangladesh)
- Rising sea levels
- **Bangladesh ⇒ prone to flooding country** with low-lying floodplains (**80%** of the country - Clarke et al. 2015)

⇒ On average, around **20-25%**of the country is yearly inundated and **55-60%** during extreme flood events (Mojid 2020).

Source: Bangladesh Department of Disaster Management, 2018

Increase in floods

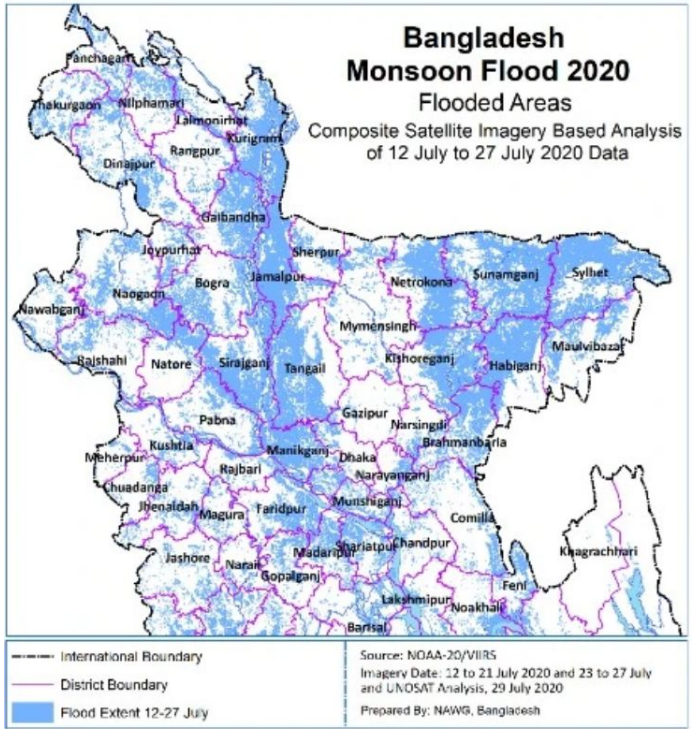
❖ Impact on the agricultural level

- One of the **major causes** of crop damage (Mojid 2020)
- Flash floods : March → May (Sutradhar et al. 2015)

- Real **threat** for **food security** & sustainable agricultural production:
  - falling crop yields, economic loss
  - loss or abandon of agricultural land

❖ Social impact

- Farmers are losing their income source



Source: Ishman et al. 2020

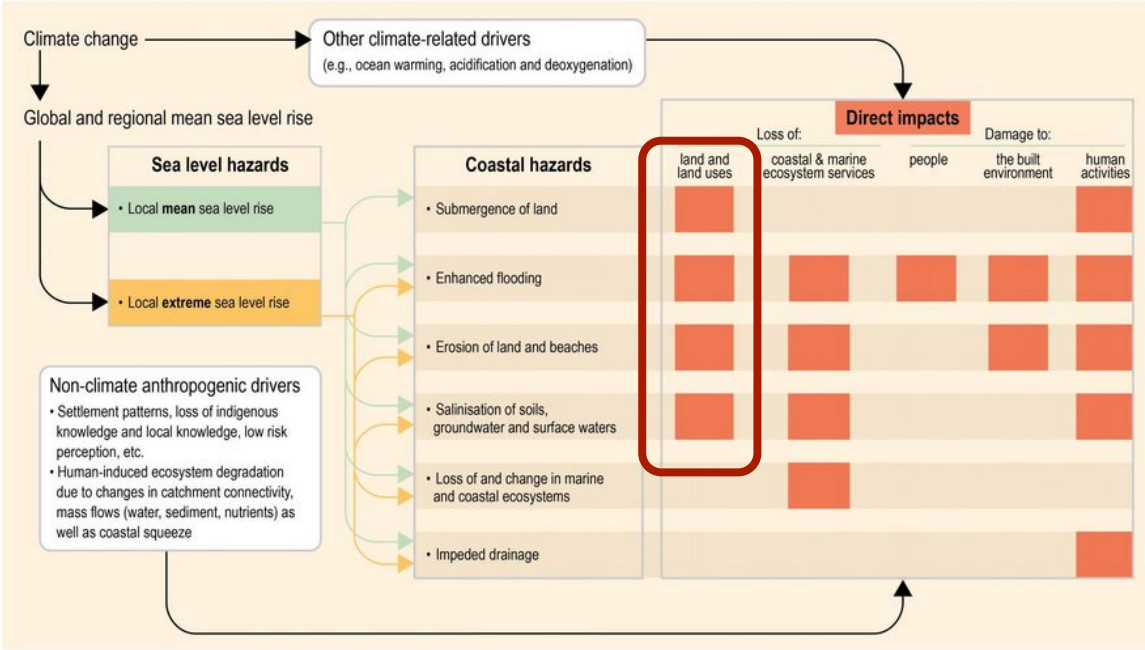
Sea level rise

- 1m sea level rise → **18 %** of Bangladesh land area would be flooded (Sarwar et al. 2007)

- Risks:
  - **Submergence** of low-lying coastal areas
  - **Saline water intrusion** (coastal rivers & groundwater aquifers)
  - Land loss due to permanent coastal erosion
  - Increasing number of floods

  ⇒ expected to increase by the end of the century along low lying coasts

  (very high confidence)



(IPCC Report, Oppenheimer et al. 2019)

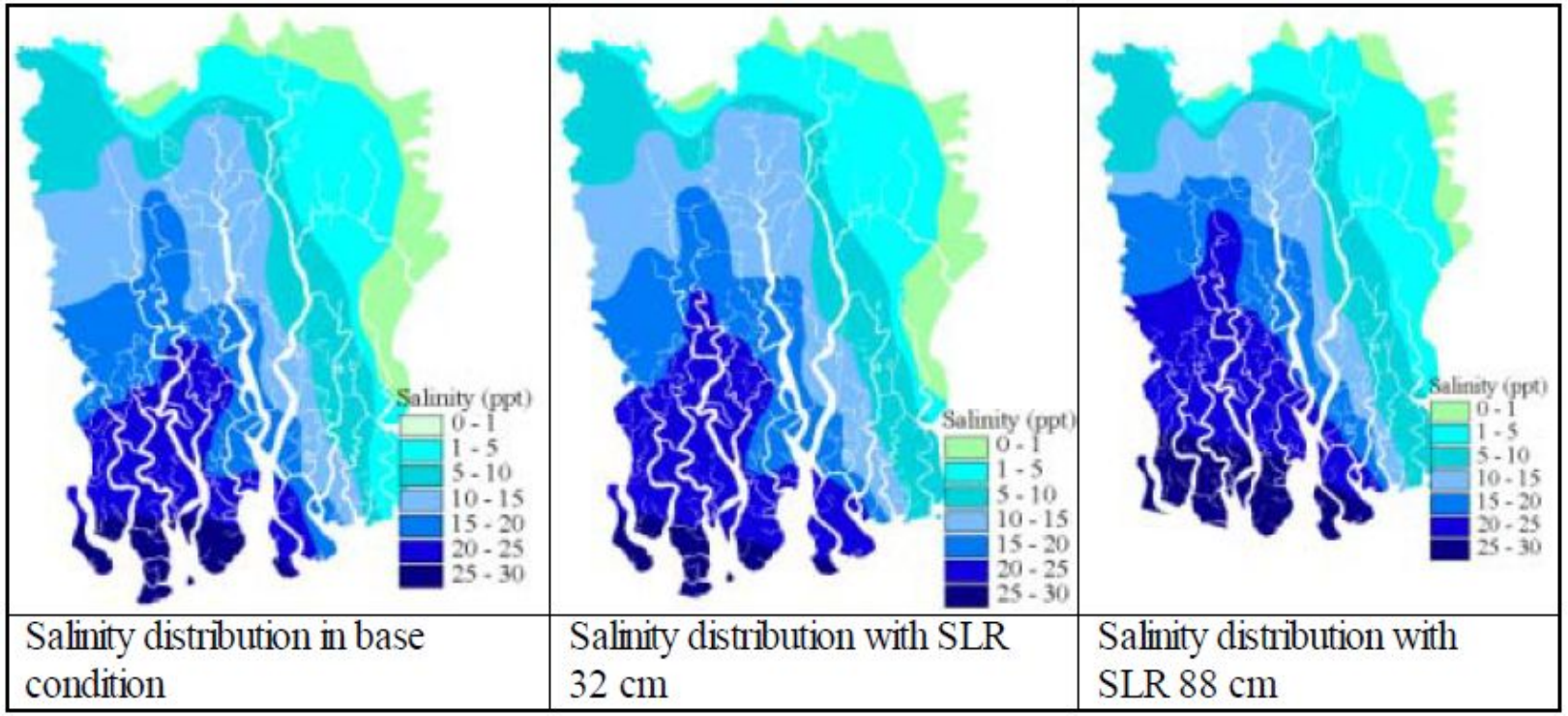
(IPCC Report on Sea Level Rise and Implications for Low-Lying Islands, Coasts and Communities)

Salinisation

- Sea level rise, natural hazards, sea water intrusion lead to salinisation
  - Additionally: Extensive shrimp farming
- Salt-water intrudes up to 100 km (southwest region, Ganges-delta)
- Reduces crop production, affects drinking water resources (human health) and biodiversity of the Sundarbans mangrove
- Saline environment has been part of Bangladesh -> people are used to it
  - Existing indigenous solutions
- 30% of cultivable land is in coastal areas where salinity is affected by tidal flooding (wet season) and movement of saline ground and surface water (dry season)

(Dasgupta, 2015)

Salinisation



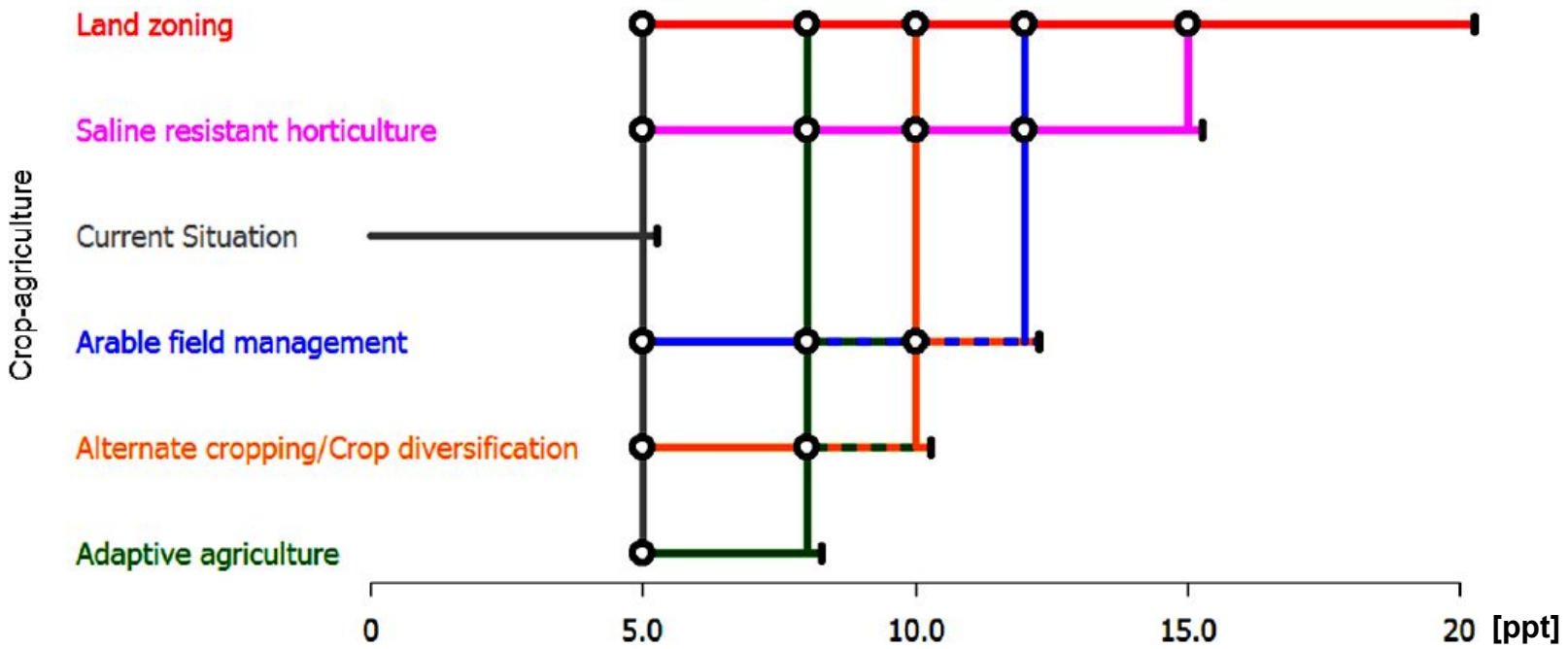
(Huque, 2009)

Adaptation Strategies

Bangladesh

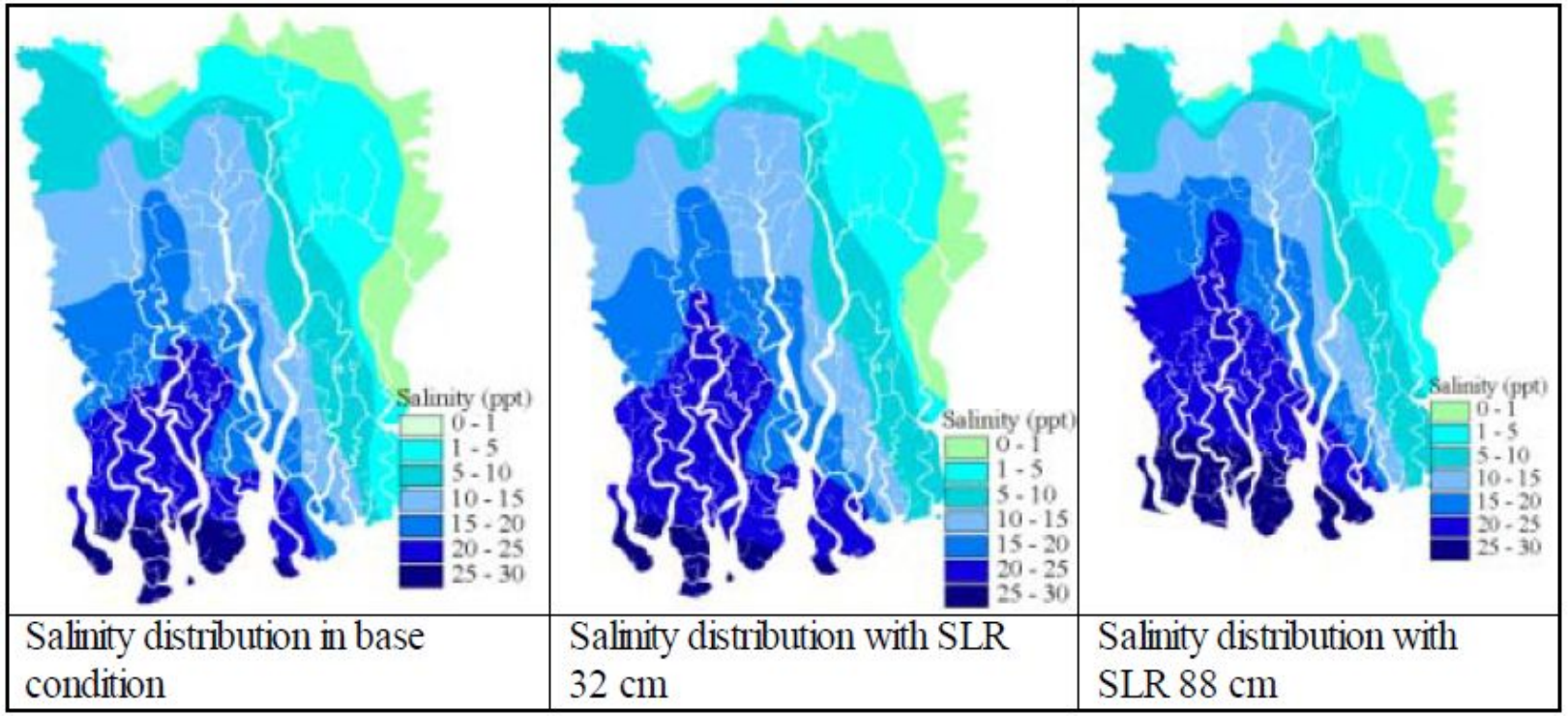
Adaptation Strategies

Salinisation - Adaptation



(Hossain, 2018)

Salinisation



(Huque, 2009)

Improved farming knowledge and change in crop varieties

❖ Use of **saline tolerant rice varieties** (Bina dhan 8, Binadhan 10, BR41, BR47, BR28) and **improvement** of **farmer's knowledge** about **sustainable agriculture practices**

- **Long term** investment
- Necessary preconditions:
  - *Farm level:* **knowledge** about improved & adaptive agriculture and **access** to saline tolerant varieties
  - *Political level:* implementation of a governmental education campaign
- Potential **limitations** of the strategy:
  - **Lack of awareness** about these saline tolerant varieties among farmers and lack of **quality seeds**
  - Important or even higher labour and fertilizer/manure/pesticides **costs**

https://www.acdivoca.org/projects/bangladesh-rice-and-diversified-crops-activity/

→ Concrete implemented strategies

- **2011**: in Bagerhat, Khulna and Satkhira: **training** on salinity resistant farming

  (80 % by the Department of Agricultural Extension)

- **2017**: small scale implemented strategy in Satkhira
  - NGO (*Solidarités International*)
  - Bangladesh government (Agriculture Extension Office)

- Provide the farmers with improved seed

  → hybrid seeds: BR-10 and BRRI dhan 4

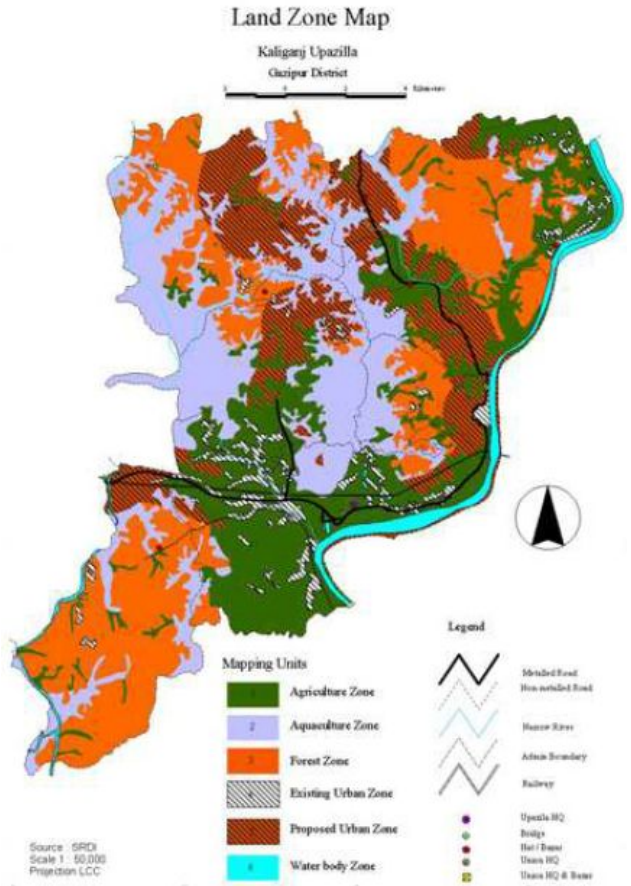
- Provide **adaptive agriculture knowledge** by improving agricultural practices

Activity	*Current annual cost, 2011 (US$)*	*Future annual cost, 2030 (US$)*
Farmers' trainings	316,354	1,528,150
Crop farming demonstrations	254,692	5,36,193
Farmers' rallies	180,965	3,61,930
Field days	5,027	7,038
Farmers' congresses	28,150	3,485
Farmers' seminars	3,016	6,032
Farmers' motivational tours	1,809	12,668
Staff capacity building	7,239	24,129
Technology fairs	12,386	16,890
FINA	7,038	0.00
IPM programme	15,416	23,056
Total	**827,064**	**2,519,571**

(Source: Mainuddin et al. 2011)

Land zoning

- Problem: huge population pressure leads to continuous human and natural interventions
  - Shrimp industry: Salt water is carried inland → higher salinisation
- Land zoning ensures land is used for specific purpose
  - e.g. agricultural, industrial, residential
- Carried out by state or local government



(Hossain, 2018 | Hossain, 2015)

Tidal river management

- History: 17th century - 1950, Zamindars (landlords) managed water resources
  - Temporary low earthen embankments during eight dry months
  - Embankments were dismantled to open the periodically flooded land for cattle grazing, open fishing on tidal flood plain
  - 1950: colonial power abolished Zamindary system → disastrous floods in 1954, 1955, 1956
- 20-year Water Master Plan: massive flood control structures
- Additionally: freshwater supply is massively reduced due to dams
- TRM: temporarily inundating floodplains
  - Restore tidal flooding
  - Ganges Barrage: idea to hold back water of the monsoon season

(Hossain, 2018 | Gain, 2017)

Floating Agriculture

- Traditional indigineous agriculture technique
- Involves planting crops on soil-less floating beds
- Construction of a floating bed:
  - The floating bed is constructed with three to five layers of water hyacinth.
  - After preparing several layers, the floating bed becomes compact due to decomposition of the water hyacinths
  - The water hyacinth bed is made at five to seven days intervals.
- Floating agriculture can be extremely effective[1]

FAO (2017)

[1] FAO, 2017

Floating Agriculture

- Economic evaluation

Annual average revenue per bed : 17611.75
Annual average cost per bed : 12369.37
Annual average net present revenue per bed (NPR) : 5242.38
Annual net revenue (NR) of 50HHs : Number of bed x NPR = 627x5242.38 = 3286972.26
Annual net revenue (NR) per HH: 65739.45
Benefit cost ratio (BCR): 1.43

Note: All values of Revenue, Cost, NPR and NR are measured in Bangladeshi Taka (BDT)

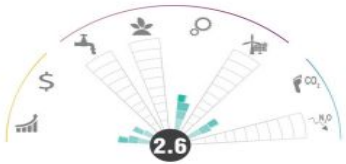
Akbar Kabir (2019)

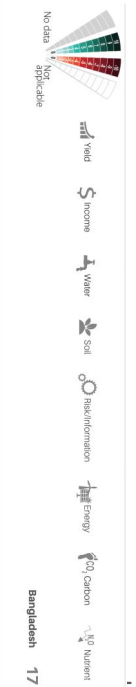
- 68% of the farmers use this technique production for business purpose[1]

[1] Akbar Kabir (2019)

Floating Agriculture: Climate-Smart Agriculture production system

World Bank. (2017)

CSA practice	Region and adoption rate (%) <30 30-60 60>	Predominant farm scale S: small scale M: medium scale L: large scale	Climate smartness	Impact on CSA Pillars
Floating beds cultivation on water bodies	Northern <30%	S		**Productivity** Increases in income due to harvesting of multiple crops in one season. Generates additional income from the sale of seedlings produced. **Adaptation** Reduce risk of complete crop failure. Allows optimum use of natuaral and local available resources. Creates additional cropping area. **Mitigation** Protects soil structure and organic carbon reserves. Promotes fuel and energy savings
Floating beds cultivation on water bodies	Southern <30%	S		**Productivity** Increases in income due to harvesting of multiple crops in one season. Generates aditional additional income from the sale of seedlings produced. **Adaptation** Reduce risk of complete crop failure. Allows optimum use of natuaral and local available resources. Creates additional cropping area. **Mitigation** Protects soil structure and organic carbon reserves. Promotes fuel and energy savings due to reduced tillage.



Conclusion

Identifying similarities and differences in adaptation strategies

- Relevant similarities:
  - Potential for introducing new crop varieties
  - Intensification of climate impacts through human activities
  - Cooperation between farmers and other stakeholders

- Important differences:
  - Requirements for water management
  - Availability of funding, research & development, technology, and subsidies
  - Farm sizes

References

Abdullah Al Pavel, M., Abdullah Chowdhury, M., & Abdullah Al Mamun, M. (2014). Economic evaluation of floating gardening as a means of adapting to climate change in Bangladesh. International Journal of Environmental Studies, 1–9. https://doi.org/10.1080/00207233.2014.911406

AGFORWARD. Summary. (n.d.). Retrieved March 31, 2022, from https://www.agforward.eu/de/silvoarable-agroforestry-in-the-uk.html

Agroforestry in the European Union - European Parliament. (n.d.). Retrieved March 31, 2022, from https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/651982/EPRS_BRI(2020)651982_EN.pdf

Ahmed, A. U., Hernandez, R., & Naher, F. (2016). Adoption of stress-tolerant rice varieties in Bangladesh. Technological and Institutional Innovations for Marginalized Smallholders in Agricultural Development, 241–255. https://doi.org/10.1007/978-3-319-25718-1_15

Alvar-Beltrán, J., Elbaroudi, I., Gialletti, A., Heureux, A., Neretin, L. Soldan, R. 2021. Climate Resilient Practices: typology and guiding material for climate risk screening. Rome, FAO

Ar6 climate change 2021:The Physical Science Basis. Sixth Assessment Report. (n.d.). Retrieved April 1, 2022, from https://www.ipcc.ch/report/ar6/wg1/

Bangladesh battles flooding caused by sea level rise and ice melt. Nextblue - Your platform about water. (n.d.). Retrieved March 31, 2022, from https://next.blue/articles/bangladesh-battles-flooding-caused-by-sea-level-rise-and-ice-melt

Bangladesh Bureau of Statistics (2019) Preliminary Report on Agriculture Census 2019. ISBN: 978-984-34-7554-1

Bangladesh climate and disaster risk atlas: Exposures, vulnerabilities, and risks - volume II (December 2021) - bangladesh. ReliefWeb. (n.d.). Retrieved April 1, 2022, from https://reliefweb.int/report/bangladesh/bangladesh-climate-and-disaster-risk-atlas-exposures-vulnerabilities-and-risks

Bangladesh. Faostat. (n.d.). Retrieved March 31, 2022, from https://www.fao.org/faostat/en/#country/16

Bangladesh Country commercial guide, International trade administration. Last updated - 23.08.2020, https://www.trade.gov/country-commercial-guides/bangladesh-agriculture-sectors

References

Bangladesh: Shocks, agricultural livelihoods and ... - fao.org. (n.d.). Retrieved March 31, 2022, from https://www.fao.org/3/cb8249en/cb8249en.pdf

Being climate-smart in agriculture. Food and Agriculture Organization of the United Nations. (2022). Retrieved March 31, 2022, from https://www.fao.org/fao-stories/article/en/c/1172370/

Better Farming Practices for resilient livelihoods in ... Better farming practices for resilient livelihoods in saline and flood-prone Bangladesh. (n.d.). Retrieved March 31, 2022, from https://www.solidarites.org/wp-content/uploads/2017/06/Better-farming-practices-for-resilient-livelihoods-in-saline-and-flood-prone-Bangladesh-1.pdf

BLE, 2022. Agroforstwirtschaft – traditionelle Systeme mit Zukunftspotentialhttps://www.oekolandbau.de/landwirtschaft/pflanze/grundlagen-pflanzenbau/regenerative-landwirtschaft/agroforstsysteme/

BMEL. (2020). Adressing climate change. https://www.bmel.de/SharedDocs/Downloads/EN/Publications/climate-change.pdf?__blob=publicationFile&v=2

BMEL. (2020). *Understanding Farming. Facts and figures about German farming.* https://www.bmel.de/SharedDocs/Downloads/EN/Publications/UnderstandingFarming.pdf?__blob=publicationFile

Buth, M. (2013, October 29). Field of Action Agriculture. Umweltbundesamt. Retrieved April 1, 2022, from https://www.umweltbundesamt.de/en/topics/climate-energy/climate-change-adaptation/impacts-of-climate-change/climate-impacts-germany/climate-impacts-field-of-action-agriculture#temperature

Central Intelligence Agency. (n.d.). Central Intelligence Agency. Retrieved April 1, 2022, from https://www.cia.gov/the-world-factbook/countries/bangladesh/

Clarke, D., Williams, S., Jahiruddin, M., Parks, K., & Salehin, M. (2015). Projections of on-farm salinity in coastal Bangladesh. Environmental Science: Processes & Impacts, 17(6), 1127–1136.https://doi.org/10.1039/c4em00682h

Climate and average weather in Germany. World Weather & Climate Information. (n.d.). Retrieved March 31, 2022, from https://weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine-in-Germany

Climate resilient practices - fao. (n.d.). Retrieved March 31, 2022, from https://www.fao.org/3/cb3991en/cb3991en.pdf

Dasgupta, S., Hossain, M. M., Huq, M., & Wheeler, D. (2015). Climate change and soil salinity: The case of coastal Bangladesh. Ambio, 44(8), 815–826. https://doi.org/10.1007/s13280-015-0681-5

deutschlandfunk.de. (2019). Hitzeresistente Ackerpflanzen - Klimawandel macht fremde Sorten für Landwirte attraktiv. Deutschlandfunk. Retrieved March 31, 2022, from https://www.deutschlandfunk.de/hitzeresistente-ackerpflanzen-klimawandel-macht-fremde-100.html

References

DWD. (August 30, 2021). Average summer temperature in Germany from 1881 to 2021 (in Celsius) [Graph]. In Statista. Retrieved March 30, 2022, from https://www.statista.com/statistics/982782/average-summer-temperature-germany/

European Parliamentary Research Service (EPRS), 2020: Agroforestry in the European Union.

https://www.europarl.europa.eu/RegData/etudes/BRIE/2020/651982/EPRS_BRI(2020)651982_EN.pdf

FAO. (2022). Bangladesh – shocks, agricultural livelihoods and food security. https://doi.org/10.4060/cb8249en

FAO. (2022). Faostat. Retrieved March 31, 2022, from https://www.fao.org/faostat/en/#data/QV

Fao.org. Bangladesh | FAO Regional Office for Asia and the Pacific | Food and Agriculture Organization of the United Nations. (n.d.). Retrieved March 31, 2022, from https://www.fao.org/asiapacific/perspectives/agricultural-statistics/global-strategy/results-in-the-region/bangladesh/en/

Faruque, G., Sarwer, R. H., Karim, M., Phillips, M., Collis, W. J., Belton, B., & Kassam, L. (2016). The evolution of Aquatic Agricultural Systems in southwest Bangladesh in response to salinity and other drivers of change. International Journal of Agricultural Sustainability, 15(2), 185–207. https://doi.org/10.1080/14735903.2016.1193424

Food and Agriculture Organization of the United Nations. (n.d.). Agroforestry. Retrieved March 31, 2022, from https://www.fao.org/forestry/agroforestry/80339/en/

Gain, A. K., Benson, D., Rahman, R., Datta, D. K., Rouillard, J. J. (2017): Tidal river management in the south west Ganges‐Brahmaputra delta in Bangladesh: Moving towards a transdisciplinary approach? ‐ Environmental Science and Policy, 75, pp. 111—120.

GDP (current US$) - bangladesh. Data. (n.d.). Retrieved March 31, 2022, from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=BD

GDP (current US$) - Germany | Data. (2021). Worldbank. Retrieved March 30, 2022, from https://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=DE

GDP per capita (current US$) - bangladesh. Data. (n.d.). Retrieved March 31, 2022, from https://data.worldbank.org/indicator/NY.GDP.PCAP.CD?locations=BD

Gendries, S. (2019, April 2). Hitzewelle und Dürre: Big data hilft bei bewässerung in der landwirtschaft. LebensraumWasser Der Wasser-Blog. Retrieved April 1, 2022, from https://www.lebensraumwasser.com/hitzewelle-und-duerre-big-data-hilft-bei-bewaesserung-in-der-landwirtschaft/

References

General profile. Food and Agriculture Organization of the United Nations. (n.d.). Retrieved March 31, 2022, from https://www.fao.org/countryprofiles/index/en/?iso3=BGD

German Agroforestry Association (defaf ... - agroforst-info.de. (n.d.). Retrieved March 31, 2022, from https://agroforst-info.de/wp-content/uploads/2021/06/2020-08-19__DeFAF-position-paper-EU-strategy-for-adaption-to-climate-change.pdf

Govindaraj, M. (2018). Breeding Cultivars for Heat Stress Tolerance in Staple Food Crops. IntechOpen.

Hossain, M. S., Qian, L., Arshad, M., Shahid, S., Fahad, S., & Akhter, J. (2019). Climate change and crop farming in Bangladesh: An analysis of economic impacts. International Journal of Climate Change Strategies and Management, 11(3), 424–440. https://doi.org/10.1108/ijccsm-04-2018-0030

Hossain, Mohammad A and Mohammad K H Dewan. “Land zoning: concept and its urgency in Bangladesh”. EC Agriculture 1.1 (2015): 57-72.

Hossain, P. R., F. Ludwig, and R. Leemans. 2018. Adaptation pathways to cope with salinization in south-west coastal region of Bangladesh. Ecology and Society 23(3):27. https://doi.org/10.5751/ES-10215-230327

IPCC. (2018). Global Warming of 1.5°C. IPCC Special Report. Summary for Policymakers. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/site/assets/uploads/2018/11/SR1.5_SPM_Low_Res.pdf

IPCC. (2019). Summary for Policymakers. In: Climate Change and Land: An IPCC special report on climate change, desertification, land degradation ... [P.R. Shukla, J. Skea, E. Calvo Buendia, V. Masson-Delmotte, H.- O. Pörtner, D. C. Roberts, P. Zhai, R. Slade, S. Connors, R. van Diemen, M. Ferrat, E. Haughey, S. Luz, S. Neogi, M. Pathak, J. Petzold, J. Portugal Pereira, P. Vyas, E. Huntley, K. Kissick, M. Belkacemi, J. Malley, (eds.)]. In press: https://www.ipcc.ch/srccl/chapter/summary-for-policymakers/

IPCC. (2021). Climate Change 2021. The Physical Science Basis. Summary for Policymakers (Contribution to the Sixth Assessment Report of The). Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_SPM_final.pdf

IPCC. (2022). Climate Change 2022. Impacts, Adaptation and Vulnerability. Summary for Policymakers. Intergovernmental Panel on Climate Change. https://www.ipcc.ch/report/ar6/wg2/downloads/report/IPCC_AR6_WGII_SummaryForPolicymakers.pdf

References

Ishmam , R., & Akter Riza, S. (n.d.). 2020 Monsoon Flood in Bangladesh - a sign of changing T... 2020 Monsoon Flood in Bangladesh - A Sign of Changing Times. Retrieved March 31, 2022, from http://www.changemag-diinsider.com/blog/2020-monsoon-flood-in-bangladesh-a-sign-of-changing-times

Islam, A. R., Shill, B. K., Salam, R., Siddik, M. N., & Patwary, M. A. (2020). Insight into farmers' agricultural adaptive strategy to climate change in northern Bangladesh. Environment, Development and Sustainability, 23(2), 2439–2464. https://doi.org/10.1007/s10668-020-00681-6

Jiang L, Wu S, Liu Y, Yang C (2021) Grain security assessment in Bangladesh based on supply-demand balance analysis. PLoS ONE 16(5): e0252187. https://doi.org/10.1371/journal.pone.0252187

Jährliche Dürrestärken in deutschland - UFZ. (n.d.). Retrieved March 31, 2022, from https://www.ufz.de/index.php?de=47252

Kabir, M. A., Moniruzzaman, M., Jahan, K., & Shahjahan, M. (2019). Cost-benefit analysis of seedling production on floating beds in a few selected areas of Bangladesh. Journal of Agricultural Studies, 7(2), 75. https://doi.org/10.5296/jas.v7i2.14788

Kamruzzaman, M., & Shaw, R. (2018). Flood and sustainable agriculture in the Haor Basin of bangladesh: A review paper. Universal Journal of Agricultural Research, 6(1), 40–49. https://doi.org/10.13189/ujar.2018.060106

Knauer, R. (2018, December 31). Getreide für alle Bedingungen. Spektrum.de. https://www.spektrum.de/news/klimawandel-neue-getreidesorten-sollen-duerre-und-hitze-ueberstehen/1615410

Landkarte. Agroforst. (2021, June 13). Retrieved March 31, 2022, from https://agroforst-info.de/agroforst-landkarte/

Lindsey, R. (n.d.). Climate change: Atmospheric carbon dioxide. Climate Change: Atmospheric Carbon Dioxide | NOAA Climate.gov. Retrieved March 31, 2022, from https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide

References

Mainuddin, K., Rahman, A., Islam , N., & Quasem, S. (2011). Planning and Costing Agriculture's Adaptation to Climate Change in the Salinity-Prone Cropping System of Bangladesh, 1–72. https://doi.org/https://www.osti.gov/etdeweb/servlets/purl/22073499 Bangladesh Centre for Advanced Studies

Metanavigation. Wetter und Klima - Deutscher Wetterdienst - Leistungen - agrowetter Beregnung. (n.d.). Retrieved April 1, 2022, from https://www.dwd.de/DE/leistungen/agrowetter_beregnung/agrobereg.html

Mojid, M. A. (2020). Climate change-induced challenges to sustainable development in Bangladesh. IOP Conference Series: Earth and Environmental Science, 423(1), 012001. https://doi.org/10.1088/1755-1315/423/1/012001

Muha Abdullah Al Pavel, Masud Abdullah Chowdhury & Md Abdullah Al Mamun (2014): Economic evaluation of floating gardening as a means of adapting to climate change in Bangladesh, International Journal of Environmental Studies

Oekolandbau: Sojabohnen. (2020). oekolandbau.de. Retrieved March 31, 2022, from https://www.oekolandbau.de/landwirtschaft/pflanze/spezieller-pflanzenbau/koernerleguminosen/sojabohnen/

Population, total - Germany | Data. (2021). Worldbank. https://data.worldbank.org/indicator/SP.POP.TOTL?locations=DE

Report on Agriculture and Rural Statistics . (n.d.). Retrieved March 31, 2022, from https://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/b343a8b4_956b_45ca_872f_4cf9b2f1a6e0/SPARS_Final_BBS_Rev_090817.pdf

Salinity in Bangladesh. Imperial College London. (n.d.). Retrieved March 31, 2022, from https://www.imperial.ac.uk/grantham/research/health/salinity-in-bangladesh/

Sarwar, G. M. (n.d.). Impacts of Sea Level Rise on the Coastal Zone of Bangladesh. Sarwar, M.G. (2005) impacts of sea level rise on coastal zone of Bangladesh. master's thesis on Environmental Science Programme, Lund University, Lund. - references - scientific research publishing. Retrieved March 31, 2022, from https://www.scirp.org/reference/ReferencesPapers.aspx?ReferenceID=2502342

References

Scherlitz, J. (n.d.). Ackerbau(m) - das agroforst-projekt in Brandenburg. Retrieved March 31, 2022, from https://www.hnee.de/de/Forschung/Interdisziplinre-Projekte/Agroforst-Langzeitprojekt-Ackerbaum/Ackerbaum-das-Agroforst-Projekt-in-Brandenburg-E10775.htm#Modellfl%C3%A4che

Sikder, R., & Xiaoying, J. (1970, January 1). Climate change impact and agriculture of Bangladesh: Semantic scholar. undefined. Retrieved March 31, 2022, from https://www.semanticscholar.org/paper/Climate-Change-Impact-and-Agriculture-of-Bangladesh-Sikder-Xiaoying/35f3d531e4f26da14266a7ec9204491d16858df7

Statista. (2022, January 21). Die Länder und Gebiete Europas nach Fläche 2021. https://de.statista.com/statistik/daten/studie/1258286/umfrage/laender-und-gebiete-europas-nach-flaeche/

Statista Research Department, & 24, F. (2022, February 24). Bangladesh: Total arable land. Statista. Retrieved March 31, 2022, from https://www.statista.com/statistics/687785/bangladesh-total-arable-land/

Sutradhar, Bala, Hasan, Islam, Rhaman, Billah, & Pavel. (2015). *A REVIEW OF GOOD ADAPTATION PRACTICES ON CLIMATE CHANGE IN BANGLADESH*. Retrieved April 1, 2022, from https://research.fit.edu/media/site-specific/researchfitedu/coast-climate-adaptation-library/asia-amp-indian-ocean/bangladesh/Sutradhar-et-al.--2015.--A-REVIEW-OF-GOOD-ADAPTATION-PRACTICES.pdf

Tauhid Ur Rahman, M., Rasheduzzaman, M., Habib, M. A., Ahmed, A., Tareq, S. M., & Muniruzzaman, S. M. (2017). Assessment of fresh water security in coastal Bangladesh: An insight from salinity, community perception and adaptation. Ocean & Coastal Management, 137, 68–81. https://doi.org/10.1016/j.ocecoaman.2016.12.005

These farmers in Bangladesh are floating their crops to adapt to climate change. Global Center on Adaptation. (2021, February 14). Retrieved March 31, 2022, from https://gca.org/these-farmers-in-bangladesh-are-floating-their-crops-to-adapt-to-climate-change/

Timsina, J., Wolf, J., Guilpart, N., van Bussel, L. G. J., Grassini, P., van Wart, J., Hossain, A., Rashid, H., Islam, S., & van Ittersum, M. K. (2018). Can Bangladesh produce enough cereals to meet future demand? Agricultural Systems, 163, 36–44. https://doi.org/10.1016/j.agsy.2016.11.003

Umweltbundesamt | Für Mensch und Umwelt. (n.d.). Retrieved March 31, 2022, from https://www.umweltbundesamt.de/sites/default/files/medien/421/publikationen/das_2019_monitoring_report_bf.pdf

References

UN-REDD Bangladesh National Program. 2016. Drivers of Deforestation and Forest Degradation in Bangladesh: Final report. UN-REDD Bangladesh National Program, 10January 2017.

US Department of Commerce, N. O. A. A. (2005, October 1). Global Monitoring Laboratory - Carbon Cycle Greenhouse Gases. GML. Retrieved March 31, 2022, from https://gml.noaa.gov/ccgg/trends/

Was Bedeutet Starkregen für die landwirtschaft? Bundesinformationszentrum Landwirtschaft: Was bedeutet Starkregen für die Landwirtschaft? (n.d.). Retrieved March 31, 2022, from https://www.landwirtschaft.de/landwirtschaft-verstehen/wie-funktioniert-landwirtschaft-heute/was-bedeutet-starkregen-fuer-die-landwirtschaft

Wasserfußabdruck: Wie viel Wasser steckt in Landwirtschaftlichen Produkten? Bundesinformationszentrum Landwirtschaft: Wie viel Wasser steckt in landwirtschaftlichen Produkten? (2022, March 23). Retrieved April 1, 2022, from https://www.landwirtschaft.de/diskussion-und-dialog/umwelt/wie-viel-wasser-steckt-in-landwirtschaftlichen-produkten

Was wächst auf Deutschlands Feldern? (n.d.). Www.Landwirtschaft.De. Retrieved March 29, 2022, from https://www.landwirtschaft.de/landwirtschaft-verstehen/wie-arbeiten-foerster-und-pflanzenbauer/was-waechst-auf-deutschlands-feldern

World Bank Climate Change Knowledge Portal. Climatology | Climate Change Knowledge Portal. (n.d.). Retrieved April 1, 2022, from https://climateknowledgeportal.worldbank.org/country/bangladesh/climate-data-historical#:~:text=Bangladesh%20has%20a%20humid%2C%20warm,and%2034%E2%81%B0C%20throughout%20the%20year

World Bank Group. (2015, February 27). Salinity intrusion in a changing climate scenario will hit coastal Bangladesh hard. World Bank. Retrieved March 31, 2022, from https://www.worldbank.org/en/news/feature/2015/02/17/salinity-intrusion-in-changing-climate-scenario-will-hit-coastal-bangladesh-hard

World Bank Open Data. (n.d.). Retrieved March 31, 2022, from https://data.worldbank.org/indicator/NY.GDP.PCAP.KD.ZCWXbxWebQOQuSdv-ClaDHd-

World Bank. (2017). Climate-Smart Agriculture in Bangladesh. CSA Country Profiles for Asia Series. International Center for Tropical Agriculture (CIAT); World Bank. Washington, D.C. 28 p.

Yaqoob, N., Ali, S. A., Kannaiah, D., Khan, N., Shabbir, M. S., Bilal, K., & Tabash, M. I. (2022). The effects of agriculture productivity, land intensification, on Sustainable Economic Growth: A panel analysis from Bangladesh, India, and Pakistan economies. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-021-18471-6

Thank you for your attention!

Discussion