| Hazard | Measure | Implementation cost | Hazard mitigation value | Implement-ation time | Life span | Expected impact | Examples of application |
|---|---|---|---|---|---|---|---|
| **Flood** | Riparian forests | $10,000 to $30,000 per acre[1];<br><br>$20,000 to $40,000 per acre[2];<br><br>From $4,000 to almost $8,000 per mile (average $5,000 per mile, or $110 per acre)[3]; | 0-24$/ha[4] | 50-100 years [5] | | 30-40% for conifers; 10-20% for broadleaves[6];<br>uplands 15-20%; lowlands 75+%[7]<br>+/-10-15%[8] ;<br><br>2.2 km reach raised flood storage by 71% and delayed the flood peak by 140 min in an 80 km² catchment[9];<br><br>977 m³/ha[10] | River Cary catchment/ Somerset[11]<br>Mount Cameroun[12] |
| **Flood** | Wetlands | $10,000 – $20,000/acre [13] [14] [15] | Around $475/ha/year [16]<br>$11,7887/ ha/year [17] | Three years or more[18] | | 1 acre wetland -><br>3 acre feet of water[19] | Egå Engsø, Denmark[20]<br><br>Danube River [21] |
| **Flood, coastal inundation, storm surge** | Coral reefs | $20 to $155,000 per meter (median $1,290 per meter [22]<br><br>1 ha/US$80000 (2010) and US$1600000 (2010) [23] | $ 189,000 /ha/year (global) [24]<br><br>$ 700,000 – 2.2 billion per year (Caribbean)[25]<br><br>$2,000/ square kilometer/year (American Samoa) [26] | 0.3 – 5 years[27] | | Coral reefs: 97% ;<br>Reef crests alone (86%) [28]<br><br>St.Lucia:<br>Coral reefs protecting 40% of island's shoreline [29] | Florida and U.S. Virgin Islands[30] |
| **Flood** | Closure gates | $3 billion [31]<br><br>0.5 – 2.5 million €[32] | $ 94 million at 2002 [33] | 15 years [34] | 25 years [35] | Chance of exceeding water level of 3,60m is reduced from once every 100 years on average to once every 10,000 years on average.[36] [37] | Venice, Italy[38]; Thames barriers, London[39] |
| **Flood** | Dykes, levees, revetments, seawalls | €270/metre to $11,200/metre [40] ;<br><br>Netherlands:<br>4 - 11 million € per km per m heightening (rural areas); | Safety level 1/500: 1997 million € ;<br>Safety level 1/1250:<br>Median 2809 million €; [45] | 5-25 years [46] | 50 to 100 years [47] ;<br><br>30 years [48] | | Netherlands [49],<br>Vietnam [50] |

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|---|---|---|---|---|---|---|---|
| | | 14 - 22 million € per km per m heightening (urban areas)[41]<br><br>4 - 8 million € per km per m heightening[42]<br><br>Vietnam:<br>0.7 – 1.2 million € per m heightening for a km stretch, maintenance: 0.02 million €/km dike/year [43] ;<br>Low river dike: 3 million €/km;<br>High river dike: 5 million €/km;<br>Estuarine dike: 5 million €/km;<br>Coastal defence: 7.5 million €/km [44] | | | | | |
| **Flood, coastal and riverbank erosion** | Groynes/Breakwaters | €4,500/metre [51]<br><br>Netherlands:<br>EUR 3,000 to 15,000/Meter (Groyne)<br>&<br>EUR 10,000 to 50,000/meter (Breakwater) [52]<br><br>Vietnam: 11.850.000 US$ per masonry (average)[53] | | Groyne: 2 months for one masonry (Vietnam) [54] | Breakwaters: 30-50 years<br><br>Wooden groyne: 10-25 years<br><br>Groynes made of gabions 1-5years [55] | Three scenarios[56] | Danish North sea coast [57]<br>Vietnam, Mekong [58] |
| **Flood** | Pump stations | $500,000 to $5,000,000[59] | | | Pump station equipment: 20 to 30 years<br><br>Pump station structures: 50 years [60] | 2.75 times the normal dry weather flow [61] ;<br><br>30 tons of water per second [62] ;<br><br>76 lpm (20 gpm) - 378,500 lpm (100,000 gpm) [63] | York, UK [64]<br>Winnipeg, Canada [65] |
| **Flood, inundation, flood wave attenuation, tsunami** | Mangroves | $91,66/ha (Vietnam) [66]<br><br>USD$ 225-216,000/ha [67] | $7.3 million/year [68];<br>US$ 300,000/ km [69] | 1508,33 ha per year [70]<br>560 ha/year (Vietnam) [71] | 15-30 years [72] | 40–50 cm/km [73] | Vietnam [74] |

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| **Flood, inundation, coastal erosion** | Beach nourishment | € 3-4 per m³ (foreshore nourishment)<br><br>€ 7-8 per m³ (beach nourishment)<br><br>€ 11 per m³ (South Africa) [75] |
| **Flood** | Floodbox | $500,000 [76] |
| **Flood** | Rip-Rap | $50/m³ [77] |
| **Flood** | Tidal marsh | $7,500/acre [78] |

[1] **Forest restoration and enhancement** (establishment of native trees species, establishment of missing vegetative strata)
http://crwp.org/files/floodplain_restoration_sw_management_march_2009.pdf

[2] **Reforestation** (res-establishment of appropriate forest communities through planting of areas that have been cleared)
http://crwp.org/files/floodplain_restoration_sw_management_march_2009.pdf ; http://www.zentner.com/images/journal_articles/wetlandandriparianwoodlandrestorationcosts.pdf

[3] (Riparian reforestation; only cost for the trees)
https://www.st.nmfs.noaa.gov/st5/Salmon_Workshop/11_Bair.pdf

[4] Flood protection, valued at value of avoidable crop and tree losses, Mount Cameroun)
https://www.cbd.int/doc/external/academic/forest-es-2003-en.pdf

[5] For riparian forest restoration
http://link.springer.com/article/10.1007/s00267-001-0066-3

[6] Reduced net rainfall under woodland due to interception loss
http://www.forestry.gov.uk/pdf/ClimateChangeSeminars_Floods_YH_140507.pdf/$FILE/ClimateChangeSeminars_Floods_YH_140507.pdf

[7] Runoff reduced for conifers
http://www.forestry.gov.uk/pdf/ClimateChangeSeminars_Floods_YH_140507.pdf/$FILE/ClimateChangeSeminars_Floods_YH_140507.pdf

[8] But marginal change for broadleaves
http://www.forestry.gov.uk/pdf/ClimateChangeSeminars_Floods_YH_140507.pdf/$FILE/ClimateChangeSeminars_Floods_YH_140507.pdf

[9] Establishing floodplain woodland
http://www.forestry.gov.uk/pdf/ClimateChangeSeminars_Floods_YH_140507.pdf/$FILE/ClimateChangeSeminars_Floods_YH_140507.pdf

[10] Additional temporary flood storage by flooplain woodplain

http://www.forestry.gov.uk/pdf/ClimateChangeSeminars_Floods_YH_140507.pdf/$FILE/ClimateChangeSeminars_Floods_YH_140507.pdf

[11] http://www.forestry.gov.uk/pdf/ClimateChangeSeminars_Floods_YH_140507.pdf/$FILE/ClimateChangeSeminars_Floods_YH_140507.pdf

[12] https://www.cbd.int/doc/external/academic/forest-es-2003-en.pdf

[13] Freshwater marsh
http://www.zentner.com/images/journal_articles/wetlandandriparianwoodlandrestorationcosts.pdf

[14] Accurate cost estimates are important for budgeting to cover all anticipated project costs, including monitoring and reporting, and that the lack of accurate budgeting has led to many projects being underfunded
http://www.aswm.org/wetland-science/planning-design/restoration-costs

[15] By using results from prior wetland valuation studies, they also estimated the average economic costs from restoration lags in Ohio and Colorado at $16,640 and $27,392 (US$2000), which are equivalent to 25% and 49% of the total restoration costs, respectively
http://www.sciencedirect.com/science/article/pii/S0169204608001448

[16] For flood control (average)
http://www.wetlandprotection.org/estimate-wetland-values.html

[17] (Luznice floodplain; Czech Republic)
https://collections.unu.edu/view/UNU:1995#viewAttachments

[18] https://fortress.wa.gov/ecy/publications/documents/93017.pdf

[19] One acre (4046.85m²) of wetland can usually store about three acre (12140.56m²) feet of water, or one million gallons (3785411.78 liters)
https://www.epa.gov/sites/production/files/2016-02/documents/flooding.pdf

[20] http://www.circle-era.eu/np4/%7B$clientServletPath%7D/?newsId=432&fileName=BOOK_150_dpi.pdf

[21] https://www.icpdr.org/main/publications/new-partnership-wetland-restoration

[22] The costs of structural coral reef restoration projects were $20 to $155,000 per meter with a median project cost of $1,290 per meter. On average, reef restoration was significantly less expensive than building tropical breakwaters (Typical costs of building tropical breakwaters ranged from $456 to $188,817 per meter with a median project cost of $19,791 per meter. These values were largely derived from U.S. Army Corp of Engineers projects.
https://www.wavespartnership.org/sites/waves/files/kc/Technical%20Rept%20WAVES%20Coastal%202-11-16%20web.pdf
http://www.nature.com/ncomms/2014/140513/ncomms4794/pdf/ncomms4794.pdf

[23] The median and average reported costs for restoration of one hectare of marine coastal habitat were around US$80000 (2010) and US$1600000 (2010)
http://onlinelibrary.wiley.com/doi/10.1890/15-1077/pdf

[24] https://collections.unu.edu/view/UNU:1995

[25] https://collections.unu.edu/view/UNU:1995

[26] https://www.wavespartnership.org/sites/waves/files/kc/Technical%20Rept%20WAVES%20Coastal%202-11-16%20web.pdf

[27] http://onlinelibrary.wiley.com/doi/10.1890/15-1077/pdf

[28] Meta-analyses reveal that coral reefs provide substantial protection against natural hazards by reducing wave energy by an average of 97%. Reef crests alone dissipate most of this energy (86%)
http://www.nature.com/ncomms/2014/140513/ncomms4794/pdf/ncomms4794.pdf

[29] http://archive.ramsar.org/pdf/info/services_03_e.pdf

[30] http://www.nature.org/ourinitiatives/habitats/oceanscoasts/howwework/restoration-works-coral-reefs.xml

[31] Venice; MOSES barriers; most costly intervention in hazard mitigation
http://unesdoc.unesco.org/images/0018/001832/183253e.pdf

[32] Unit costs related to hydraulic head over barrier (m)
http://repository.tudelft.nl/islandora/object/uuid:604825d4-f218-40fc-b3b5-5f4280b2338d/?collection=research

[33] St. Petersburg, Russia: The total average annual direct damage was estimated at USD 94 million at 2002 prices, and would now be substantially higher. This excluded any estimate of the cost of damage to the contents of buildings of cultural value, largely located in the low lying city centre, including the Hermitage and many other museums
http://eprints.hrwallingford.co.uk/603/1/HRPP569_The_St_Petersburg_Flood_Protection_Barrier_-_Design_and_Construction.pdf

[34] http://climate-adapt.eea.europa.eu/metadata/adaptation-options/storm-surge-gates-flood-barriers/#implementation

[35] http://climate-adapt.eea.europa.eu/metadata/adaptation-options/storm-surge-gates-flood-barriers/#implementation

[36] Thanks to the New Waterway Rotterdam Storm Surge Barrier the chance of exceeding in Rotterdam a water level of 3,60m above 56 Amsterdam Ordnance Datum (NAP) is reduced from once every 100 years on average to once every 10,000 years on average. The failure risk of the barrier itself is only once in 10,000,000 years.
http://www.aia.org/aiaucmp/groups/aia/documents/pdf/aias076749.pdf

[37]
http://s3.amazonaws.com/academia.edu.documents/36709515/JMEE_MB21_06.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1472122008&Signature=F%2BBzU3kzJL1juW30kZ3ITWZdqow%3D&response-content-disposition=inline%3B%20filename%3DThe_projected_MOSE_barriers_against_floo.pdf

[38]
http://s3.amazonaws.com/academia.edu.documents/36709515/JMEE_MB21_06.pdf?AWSAccessKeyId=AKIAJ56TQJRTWSMTNPEA&Expires=1472122008&Signature=F%2BBzU3kzJL1juW30kZ3ITWZdqow%3D&response-content-disposition=inline%3B%20filename%3DThe_projected_MOSE_barriers_against_floo.pdf

[39] https://www.gov.uk/guidance/the-thames-barrier

[40] Can vary a lot from small seawall (€270/metre) to large seawall for the protection of a road ($11,200/metre)
http://unesdoc.unesco.org/images/0018/001832/183253e.pdf

[41] For the Netherlands the unit costs for strengthening of dikes range between 4 and 11 M per km per m heightening for rural areas and between 14 and 22 million € per km per m heightening for urban areas (2009 price levels).
http://repository.tudelft.nl/islandora/object/uuid:604825d4-f218-40fc-b3b5-5f4280b2338d/?collection=research

[42] The cost estimates for dike and floodwall heightening for New Orleans are between 4 and 8 million € per km per m heightening
http://repository.tudelft.nl/islandora/object/uuid:604825d4-f218-40fc-b3b5-5f4280b2338d/?collection=research

[43] https://www.google.de/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwi-vunmm9zOAhVIVRoKHbbPDsIQFggeMAA&url=http%3A%2F%2Frepository.tudelft.nl%2Fassets%2Fuuid%3A59fd0624-9ad9-4eb7-ad9c-14164e904dfc%2FReport_Safety_Standards_May2008.pdf&usg=AFQjCNG2KqEHb8JnvQh2hEwT_3X51UX-kg&cad=rja

[44] Experience with dike re-enforcement in the Netherlands has yielded the following indicative estimates of total cost: low river dike: 3 million €/km; high river dike: 5 million €/km; estuarine dike: 5 million €/km; coastal defence: 7.5 million €/km
http://climate-adapt.eea.europa.eu/metadata/adaptation-options/adaptation-or-improvement-of-dikes-and-dams/#implementation

[45] Safety level 1/500 (construction costs: 331 million €) Maximum 2872 million €; Median 1997 million €; Minimum 726 million € ;
Safety level 1/1250 (construction costs: 375 million €) Maximum 4089 million €; Median 2809 million €; Minimum 994 million €
http://library.wur.nl/ebooks/hydrotheek/1761062.pdf

[46] http://climate-adapt.eea.europa.eu/metadata/adaptation-options/adaptation-or-improvement-of-dikes-and-dams/#implementation

[47] Small scale to large scale 50 to 100 years
https://books.google.de/books?id=-d59BwAAQBAJ&pg=PA351&lpg=PA351&dq=lifespan+of+dikes&source=bl&ots=UM7FF8KokB&sig=Yzz20VBxnUiivDyP_RnhmGA471g&hl=de&sa=X&ved=0ahUKEwjLro-GwtzOAhVDthoKHfw6BH8Q6AEIHDAA#v=onepage&q=lifespan%20of%20dikes&f=false

[48] http://climate-adapt.eea.europa.eu/metadata/adaptation-options/adaptation-or-improvement-of-dikes-and-dams/#implementation

[49] http://repository.tudelft.nl/islandora/object/uuid:604825d4-f218-40fc-b3b5-5f4280b2338d/?collection=research

[50] https://www.google.de/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwi-vunmm9zOAhVIVRoKHbbPDsIQFggeMAA&url=http%3A%2F%2Frepository.tudelft.nl%2Fassets%2Fuuid%3A59fd0624-9ad9-4eb7-ad9c-14164e904dfc%2FReport_Safety_Standards_May2008.pdf&usg=AFQjCNG2KqEHb8JnvQh2hEwT_3X51UX-kg&cad=rja

[51] http://unesdoc.unesco.org/images/0018/001832/183253e.pdf

[52] In the Netherlands, groynes are estimated to cost about EUR 3,000 to 15,000 per running meter. Breakwaters are estimated to cost about EUR 10,000 to 50,000 per running meter
http://climate-adapt.eea.europa.eu/metadata/adaptation-options/groynes-breakwaters-and-artificial-reefs

[53] http://www.jica.go.jp/project/vietnam/031/materials/ku57pq00001y1feh-att/mekong_groynes_en.pdf

[54] http://www.jica.go.jp/project/vietnam/031/materials/ku57pq00001y1feh-att/mekong_groynes_en.pdf

[55] Breakwaters have a typical design lifetime of 30-50 years. This is the case for most rock structures. Wooden groynes have a lifetime of about 10-25 years; and groynes made of gabions of 1-5years
http://climate-adapt.eea.europa.eu/metadata/adaptation-options/groynes-breakwaters-and-artificial-reefs

[56] http://www.coastalwiki.org/wiki/Groynes_as_shore_protection

[57] http://www.coastalwiki.org/wiki/Groynes_as_shore_protection

[58] http://www.jica.go.jp/project/vietnam/031/materials/ku57pq00001y1feh-att/mekong_groynes_en.pdf

[59] http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/cost_of_adaptation-final_report_oct2012.pdf

[60] The useful life of pump station equipment is typically limited to 20 to 30 years, with good maintenance. Pump station structures typically have a useful life of 50 years
https://www3.epa.gov/npdes/pubs/in-plant_pump_station.pdf

[61] They can carry up to a minimum of 2.75 times the normal dry weather flow
http://www.winnipeg.ca/waterandwaste/sewage/floodPump/activity.stm

[62] capable of pumping 30 tons of water per second
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/297448/gene1208bpbw-e-e.pdf

[63] Pump station capacities range from 76 lpm (20 gpm) to more than 378,500 lpm (100,000 gpm). Pre-Fabricated pump stations generally have capacity of up to 38,000 lpm (10,000 gpm). Usually, pump stations include at least two constant-speed pumps ranging in size from 38 to 75,660 lpm (10 to 20,000 gpm) each and have a basic wet-well level control system to sequence the pumps during normal operation
https://www3.epa.gov/npdes/pubs/in-plant_pump_station.pdf

[64] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/297448/gene1208bpbw-e-e.pdf

[65] http://www.winnipeg.ca/waterandwaste/sewage/floodPump/activity.stm

[66] http://www.proactnetwork.org/proactwebsite_3/images/Documents/Publications/ProAct_Projects_Reports/3.2.8.em_ecoeng_in_drr_cca.pdf

[67] Reported costs of mangrove restoration range from USD$ 225-216,000/ha

http://www.fao.org/forestry/10560-0fe87b898806287615fceb95a76f613cf.pdf

[68] Reduction of sea dyke maintenance cost by $7.3 million/year
http://www.proactnetwork.org/proactwebsite_3/images/Documents/Publications/ProAct_Projects_Reports/3.2.8.em_ecoeng_in_drr_cca.pdf

[69] In Malaysia the value of intact mangrove swamps for storm protection and flood control has been estimated at US$ 300,000 per km which is the cost of replacing them with rock walls
http://nidm.gov.in/PDF/pubs/Ecosystem%20Approach.pdf

[70] Between 1989 and 1995 9,050 ha (1508,33 ha per year) of mangroves were planted in West Bengal, India with only a 1.52% success rate
http://www.fao.org/forestry/10560-0fe87b898806287615fceb95a76f613cf.pdf

[71] http://www.ifrc.org/Global/Publications/disasters/reducing_risks/Case-study-Vietnam.pdf

[72] It has been reported that mangrove forests around the world can self-repair or successfully undergo secondary succession over periods of 15-30 years if: 1) the normal tidal hydrology is not disrupted and 2) the availability of waterborne seeds or seedlings (propagules) of mangroves from adjacent stands is not disrupted or blocked
http://www.fao.org/forestry/10560-0fe87b898806287615fceb95a76f613cf.pdf

[73] 40–50 cm/km across the mangrove forest
https://www.wavespartnership.org/sites/waves/files/kc/Technical%20Rept%20WAVES%20Coastal%202-11-16%20web.pdf

[74] http://www.ifrc.org/Global/Publications/disasters/reducing_risks/Case-study-Vietnam.pdf

[75] For beach nourishment in the Netherlands the available literature sources indicate a unit cost price of about € 3-4 per m³ material for foreshore nourishment and € 7-8 per m³ material for beach nourishment. A somewhat higher unit cost € 11 per m³ material for beach nourishment has been obtained for South Africa
http://repository.tudelft.nl/islandora/object/uuid:604825d4-f218-40fc-b3b5-5f4280b2338d/?collection=research

[76] http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/cost_of_adaptation-final_report_oct2012.pdf

[77] http://www.env.gov.bc.ca/wsd/public_safety/flood/pdfs_word/cost_of_adaptation-final_report_oct2012.pdf

[78] http://www.zentner.com/images/journal_articles/wetlandandriparianwoodlandrestorationcosts.pdf