Guidelines for inventories of tropical peatlands to facilitate their designation as Ramsar Sites: Background notes

I. Key sources of information

Spatially explicit soil information of various spatial resolutions is available in the following open access online archives:

Source	Website
International Soil Reference and Information Centre (ISRIC World Soil Information)	http://www.isric.org/.
European Union Joint Research Centre	https://ec.europa.eu/jrc/en.
FAO Corporate Document Repository	http://www.fao.org/documents/search/en/.
Institute de Recherche pour le Développent : Base de données Sphaera du service Cartographie	http://www.cartographie.ird.fr/sphaera.
World Soil Survey Archive and Catalogue (WOSSAC)	http://www.wossac.com.
Perry-Castañeda Library Map Collection, University of Texas at Austin	http://www.lib.utexas.edu/maps/topo/.
Ghent University Laboratory of Soil Science	http://www.labsoilscience.ugent.be/Congo.
Commonwealth Scientific and Industrial Research Organization: Land Research Surveys	http://www.publish.csiro.au/nid/289/aid/16088.
International Peatland Society: Publications	www.peatlands.org.
International Mire Conservation Group: Publications	www.imcg.net/pages/publications/papers.php.
Greifswald Mire Centre	http://greifswaldmoor.de/about-us.html.
Wetlands International: Peatland Treasures	https://www.wetlands.org/our-approach/peatland-treasures/.
Ramsar Recommendation 7.1: A global action plan for the wise use and management of peatlands	https://www.ramsar.org/document/recommendation-71-a-global-action-plan-for-the-wise-use-and-management-of-peatlands.
Directory of Soil Institutions and soil experts in Africa	http://www.apipnm.org/swlwpnr/reports/y_sf/sftb221.htm.
Center for International Forestry Research (CIFOR) and the United States Forest Service: Sustainable Wetlands Adaptation and Mitigation Program (SWAMP) Global Wetlands Map	https://www.cifor.org/global-wetlands/

Other sources:

Comprehensive scientific information on various topics and research related with Tropical peatlands (focus on Peat Swamp forests of SE Asia):

- Osaki, M. & Tsuji, N. (eds.) (2016). *Tropical peatland ecosystems*. Springer: Japan.

Information and tools for conservation, rehabilitation and sustainable use of peatlands:

- Joosten H., Tapio-Biström M.-L. & S. Tol (eds.) (2012). *Peatlands - guidance for climate change mitigation through conservation, rehabilitation and sustainable use*. Mitigation of Climate Change in Agriculture Series No. 5 (2nd edition). Rome, Italy: United Nations Food and Agriculture Organization, Mitigation of Climate Change in Agriculture Programme, University of Greifswald and Wetlands International. Available at: http://www.fao.org/3/a-an762e.pdf.

- Vegetation map for South America: http://forobs.jrc.ec.europa.eu/products/veget_map_tropical-sam/southamerica.php.

GIS dataset to Identify areas in tropical lowlands with permanent high water levels (cf. Gumbricht et al. 2017); downloadable GIS-data at: https://data.cifor.org/dataset.xhtml?persistentId=doi:10.17528/CIFOR/DATA.00029.

Please note, that this dataset gives only an approximation of peat distribution in tropical lowlands (not coverage of mountain peatlands) and needs further field data for verification and validation.

The Sustainable Wetlands for Mitigation and Adaptation Program (SWAMP) Toolbox enables users understand the key role of wetlands in storing carbon and contributing to climate change adaptation and mitigation strategies. Available at: http://www.cifor.org/swamp-toolbox/presentations/.

World Database of Key Biodiversity Areas: provides information on internationally significant Key Biodiversity Areas (KBAs), including global KBAs, regional KBAs and those which global/regional status is not yet determined.. Available at: http://www.keybiodiversityareas.org/site/mapsearch

Additional anecdotal data

More anecdotal supplementary data can be obtained from a wide range of sources, including publications and grey literature on wetland, peatland and organic soil research and protection, palaeo-ecological, pedological, geological and botanical research, as well as expedition reports, technical reports from private companies and environmental organisations, and incidental descriptions.

To locate data (including proxy data) on the occurrence of peatland and organic soil, relevant research institutes, government ministries or agencies can be contacted. Data on organic soil are generally elaborated by and stored at various national government levels. Relevant national authorities may include those dealing with agriculture, forestry, resource extraction, geology or environment. Considering the local terms used for peatlands and organic soils, it is important to get familiar with such terminology and concepts before contacting local authorities and researchers.

If direct data on the distribution of peatlands and organic soils are lacking, indirect information can indicate the presence of wet conditions and possibly peat. This include data on particular soil conditions (e.g., 'hydromorphic soil' or 'wetland soil'), bedrock (for example, 'young alluvium', 'lacustrine sediments'), relief (e.g. 'inundated depression'), vegetation (e.g., 'Peat Swamp Forest', 'Raphia palms', 'Papyrus reeds'), or land use and land cover ('poorly drained', 'inundation'; cf. Barthelmes et al. 2015).

List of relevant tropical peatland countries and regions with references to key sources of information

Latin America

Amazon region

- The Amazon Waters Initiative of the Wildlife Conservation Society. http://amazonwaters.org/wetlands/types/.

Argentina

- Sources of information on the Iberá Wetlands (Esteros del Iberá):
    - Ecoregion Iberá. http://www.fvsa.org.ar/situacionambiental/Ibera.pdf.
    - Ojo del Condor Journal (2nd issue, April 2012). http://ign.gob.ar/descargas/elojodelcondor/Ojo_del_Condor_02.pdf.
    - Iberá Park. http://www.proyectoibera.org/parqueibera.htm.
    - The Conservation's Land Trust Iberá Project. http://cltargentina.org/.

Brazil

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- *National Soil Maps (EUDASM)*. European Soil Data Centre (ESDAC), Joint Research Centre. https://esdac.jrc.ec.europa.eu/resource-type/national-soil-maps-eudasm?page=10 .

- Suszczynski, E.F. (1984). *Peat resources of Brazil*. Proceedings: 7th International Peat Congress Dublin, Ireland, 18-23 June 1984. Vol. 1: 468-492.Dublin, Ireland: Irish National Peat Committee.

Colombia

- *ARcGIS Map of Colombian soils ('Mapa de suelos de Colombia')*, Instituto Geográfico Agustín Codazzi (IGAC): depicts 'Histosols,' mainly aggregated with other soil types.
    - Dataset available at: http://www.arcgis.com/home/item.html?id=7cc186f61cb8482081fdf0256f47f51b (updated 17 November 2017).
    - Map viewer available at the IGAC Geoportal at: http://geoportal.igac.gov.co/es.

- López Hoyos, A. & Cortés Lombana, A. (1978). *Los suelos orgánicos de Colombia: su origen, constitución y clasificación*. Bogotá, D.E., Colombia: Ministerio de Hacienda y Crédito Público and Instituto Geográfico Agustín Codazzi, Subdirección Agrológica.

- Rangel-Churio, J.O. (ed.) (n.d.). *Colombia, biotic diversity (Diversidad Biótica)*. Vols. 9, 10 and 13. Bogotá, D.E., Colombia: Instituto de Ciencias Naturales, Facultad de Ciencias Universidad Nacional de Colombia. Available at:

http://www.colombiadiversidadbiotica.com/Sitio_web/Bienvenida.html (including research on high mountain peat environments and lowland marsh environments).

- Rangel-Churio., J.O. & Pinto-Zárate, J.H. (2012). Colombian Páramo Vegetation Database (CPVD) - the database on high Andean páramo vegetation in Colombia. *Biodiversity & Ecology*, 4: 275-286.

French Guyana

- Chaneac, L. & Legrand, C. (2009). *Bibliographic synthesis on wetlands in the Guyana* (Synthèse bibliographique sur les zones humides de Guyane). Final report. Report Bureau de Recherches Géologiques et Minières (BRGM) RP-57709-FR. BRGM. : France. Available at: http://www.brgm.fr/publication/pubDetailRapportSP.jsp?id=RSPBRGM/RP-57709-FR.

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http://www.cartographie.ird.fr/sphaera/images/telechargement/00804.pdf. Accessed 24 May 2018.

Guyana

- *General soil map of British Guiana*. European Soil Data Centre (ESDAC), Joint Research Centre. http://esdac.jrc.ec.europa.eu/images/Eudasm/latinamerica/images/maps/download/gy12000_1so.jpg. Accessed 24 May 2018.

- *Map for the reconnaissance soil survey of Northeast British Guiana*. European Soil Data Centre (ESDAC), Joint Research Centre. http://esdac.jrc.ec.europa.eu/images/Eudasm/latinamerica/images/maps/download/gy13002_3so.jpg. Accessed 24 May 2018.

- *Map for the reconnaissance soil survey of Northwest British Guiana*. European Soil Data Centre (ESDAC), Joint Research Centre. http://esdac.jrc.ec.europa.eu/images/Eudasm/latinamerica/images/maps/download/gy13002_1so.jpg. Accessed 24 May 2018.

- *Preliminary Vegetation Map of Guyana*. Biological Diversity of the Guianas Program. Smithsonian National Museum of Natural History. http://botany.si.edu/bdg/vegmap.html. Accessed 24 May 2018.

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South Sudan

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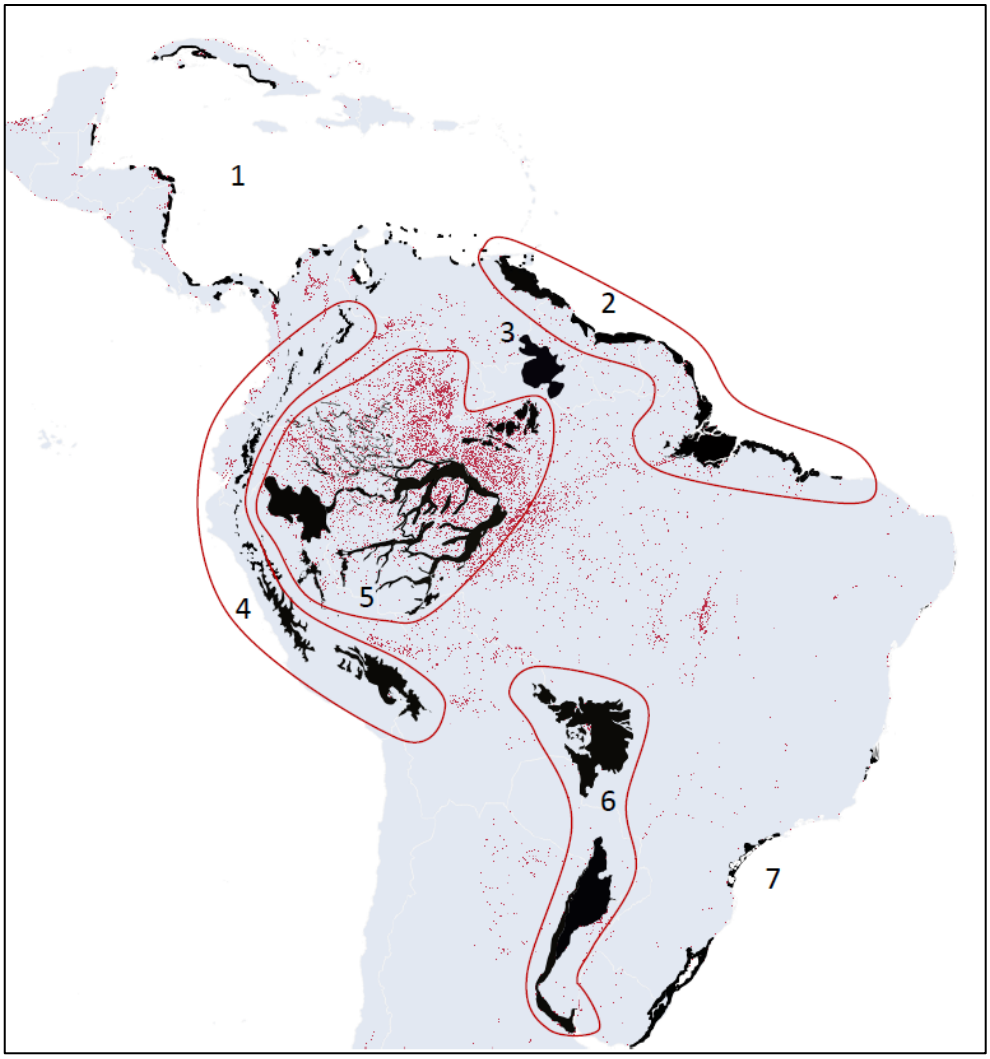
II. Tropical and subtropical terrestrial ecoregions with substantial peat and organic soil occurrences

(Source: Dinerstein et al. 2017)

The following maps, backed by scientific research and literature, show ecoregions in the Tropics and Subtropics where peatlands occur extensively (see Section I). These maps can indicate where to start with the assessments of peatlands. However, peatlands also occur besides these ecoregions, as deduced from the 'peat' GIS data from the Global Wetlands V2 (see the red dots in the maps below; Gumbricht et al. 2017). Mangroves have been included in the map, since they frequently contain highly organic soils. However, most mangrove soils will have lower carbon content.

Figure 1: Terrestrial ecoregions with substantial peat and organic soil occurrences in Central and South America



(black):

1-Caribbean: coastal swamps and mangroves;
2-Orinoco Delta: swamp forest, Guiana: peat swamp forests, Amazon Orinoco: Southern Caribbean mangroves,
3-Guyana highlands;
4-High Andean paramos and wet puna;
5-Mixed Amazon wetland vegetation: Rio Negro campinarana, Purus várzea and Iquitos várzea;
6-Pantanal, Humid Chaco and Parana flooded grassland and savannah; and
7-Brazil and Uruguay coastal swamps, mangroves and restingas.

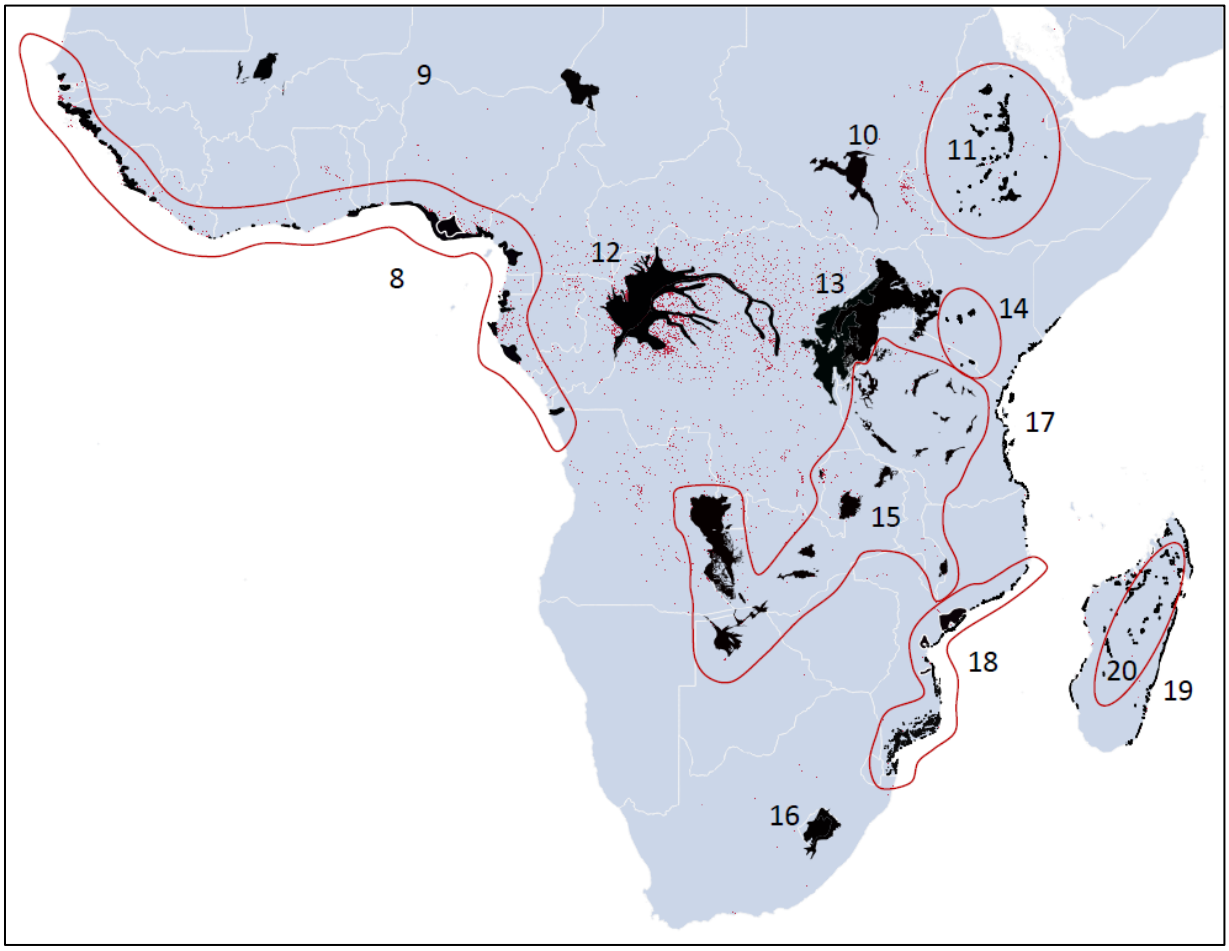


Figure 2: Terrestrial ecoregions with substantial peat and organic soil occurrences in Africa (black areas):
8-Western and Central African coastal swamps and mangroves, Niger Delta swamp forest, Central African mangroves and coastal wetlands;
9-Lake Chad and Inner Niger Delta flooded grassland and savannah;
10-Sudd flooded grassland;
11-Ethiopian montane moorlands;
12-Congolian swamp forest;
13-Victoria Basin forest and savannah swamps and Albertine Rift montane swamps;
14-East African montane moorlands;
15-Zambezi flooded grassland;
16-Drakensberg montane grasslands;
17-East African coastal mangroves and coastal wetlands;
18-Southern Mozambique coastal flooded grassland;
19-Madagascar mangroves and coastal wetlands; and
20-Madagascar montane swamps.

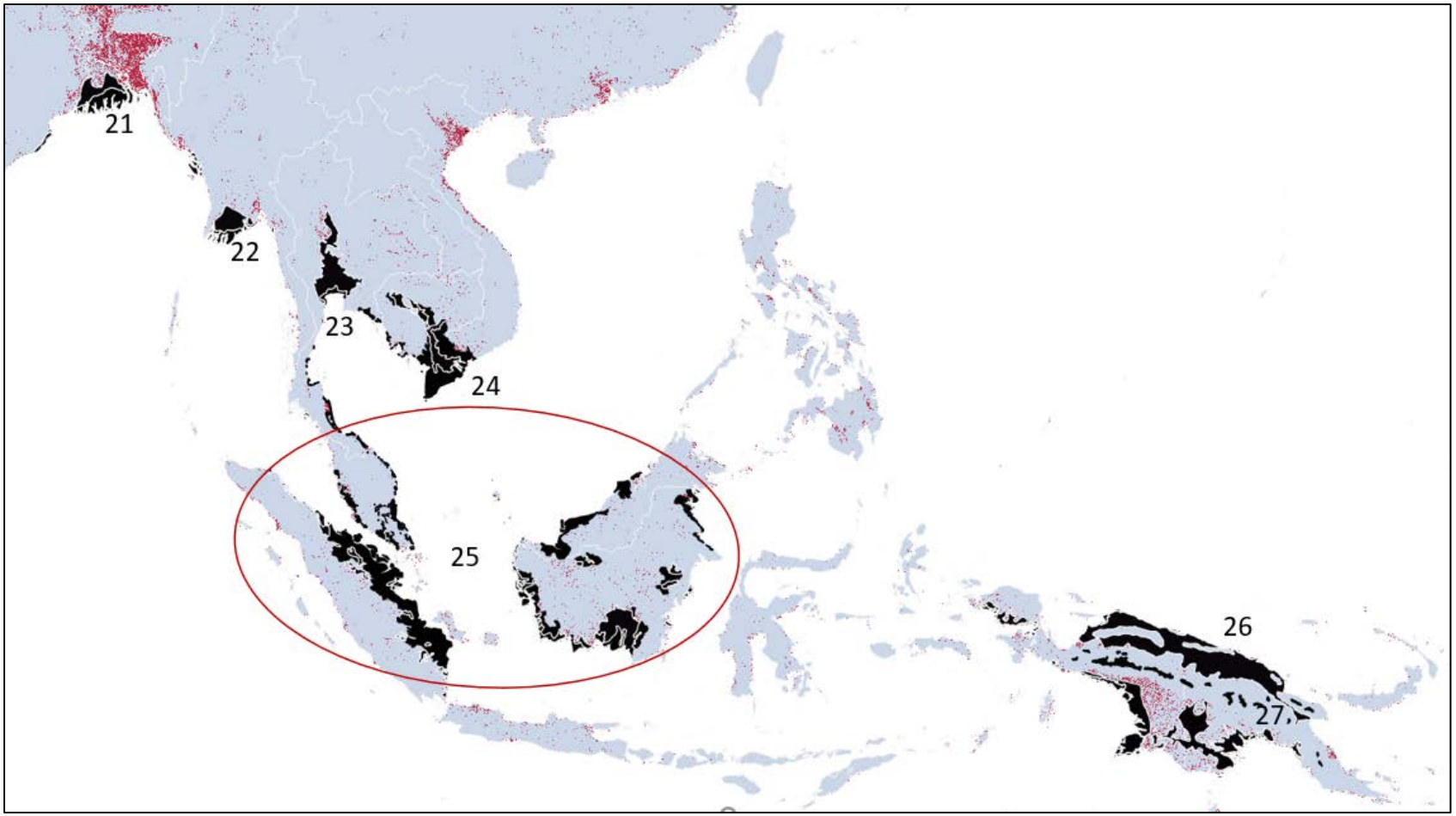


Figure 3: Terrestrial ecoregions with substantial peat and organic soil occurrences in Southeast Asia:
21-Sundarbans freshwater swamp forest and Sundarbans mangroves;
22-Irrawaddy freshwater swamp forest and Sundarbans mangroves;
23-Chao Phraya freshwater swamp forest and Indochina mangroves;
24-Tonlé Sap-Mekong peat swamp forest, Tonlé Sap freshwater swamp forest and Indochina mangroves;
25-Peninsular Malaysia peat swamp forest; Sumatran peat swamp forest, Sumatran freshwater swamp forest, Sunda Shelf mangroves, Borneo peat swamp forest, Borneo freshwater swamp forest;
26-Southern New Guinea freshwater swamp forest, New Guinea mangroves, Northern New Guinea lowland rain and freshwater swamp forest; and
27-Papua New Guinea central range sub-alpine grassland.

III. Assessment of peatland degradation (from satellite images and field work)

A: No peatland degradation (Lake Bangweulu swamps, Zambia; satellite image: Bing Aerial 2015)

- Drainage system:
  - no ditches
- Land use:
  - no or adapted to water levels at the peatland surface
- Vegetation or peat removal:
  - no bare peat and peat removal

B: Slight peatland degradation (Akanyaru River valley, Rwanda; satellite image: Bíng Aerial 2015)

- Drainage system:
  - shallow drainage of peatlands or their margins only
  - few drainage ditches with connection to main water outlet channel
  - ditches small, often irregular, or overgrown
- Land use:
  - predominantly subsistence agriculture
- Vegetation or peat removal:
  - partly removal of vegetation for cultivating crops
  - small scale peat digging and displacing to form elevated fields on-site (e.g. in Subsahara Africa)
  - small areas of bare peat

C: Heavy peatland degradation (Nyamuswaga River valley, Burundi; Bing Aerial 2015)

- Drainage system:
  - deep drainage through dense and often regular net of drainage ditches with connection with connection to main water outlet channel
  - drainage ditches broad, often regular and well maintained
- Land use:
  - industrial and high output agriculture or palm plantations
- Vegetation and peat removal
  - complete removal of peatland vegetation
  - large areas of bare peat
  - large scale peat extraction for different off-site purposes

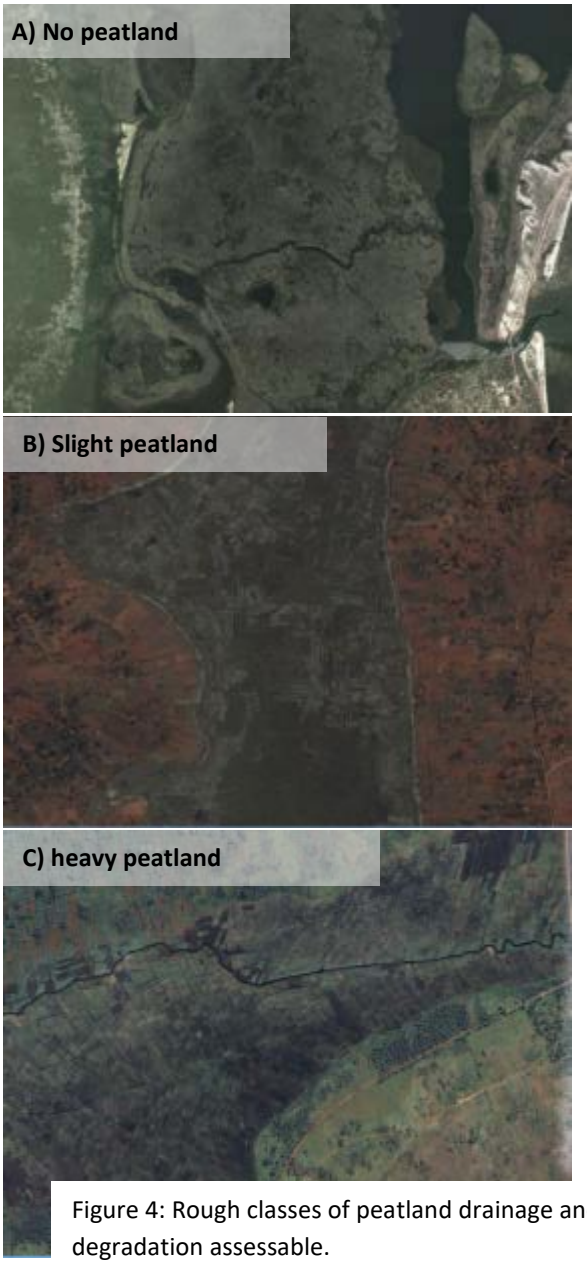


Figure 4: Rough classes of peatland drainage and degradation assessable.

IV. Case study for peatland mapping using the proposed methodology (draft)

The methodology, outlined in the case study below, was developed during the last few years after recognizing that comprehensive and reliable geospatial data for peatlands and organic soils is very scarce, especially in tropical countries. The methodology focusses on the integration of existing maps, the use of available GIS tools and (at best) the integration of field data, using freely available digital maps, GIS programs, remote sensing tools and satellite images. Peatland probability maps, as a basis for field surveys for validation of peat, are generated using the information mentioned above. When GIS technology is not available, suitable information can also be drawn on a printed topographic map - the most important preparatory step is the thorough search for suitable and available information and integrating it.

The approach has been applied recently to locate coastal peatlands and organic soils in the Caribbean region. The desk study used digital maps which indicated peat location, organic soil and suitable proxies, such as specific wetland information (see the section on "Using existing maps for identifying peatlands" in the Ramsar Briefing Note *Guidelines for conducting tropical peatland inventories to facilitate their designation as Ramsar Sites*, and Section I above). Figure 5 below shows the geographic coverage of the digital maps considered. Out of these maps, a total of 35 maps have been deemed suitable for indicating peatlands and organic soils in the Caribbean.

While using the example of Nicaragua below, these methods will be explained in more detail.

Eight digital maps were chosen for the country, which indicate:

- peat (Histosols or organic soils),
- specific wetland vegetation:
  - Mangroves,
  - Swamp with herbaceous vegetation),
  - Palm (Yolillo: *Raphia taedigera*),
  - Coastal swamp vegetation
  - Marshy coastal vegetation,
  - Swamp with Cyperaceae: sedges, or
- land cover:
  - Land subject to flooding; see Figure 3

The selected maps have been geo-referenced and integrated into a freely available GIS (Quantum GIS) program, available at https://www.qgis.org/en/site/). All single areas of the 'peat' categories, 'specific wetland vegetation', and 'land cover' have been transmitted into the GIS 1 to 1 and superimposed. Together they point to extensive wetlands along the Caribbean shore of Nicaragua, which hosts, at least partly, peatlands or organic soils. The resulting overview map is shown in Figure 6 below. It suggests a large potential peatland area in the Región Autónoma del Atlántico Norte, south of Puerto Cabezas – as shown by the thick black frame in Figure 6.

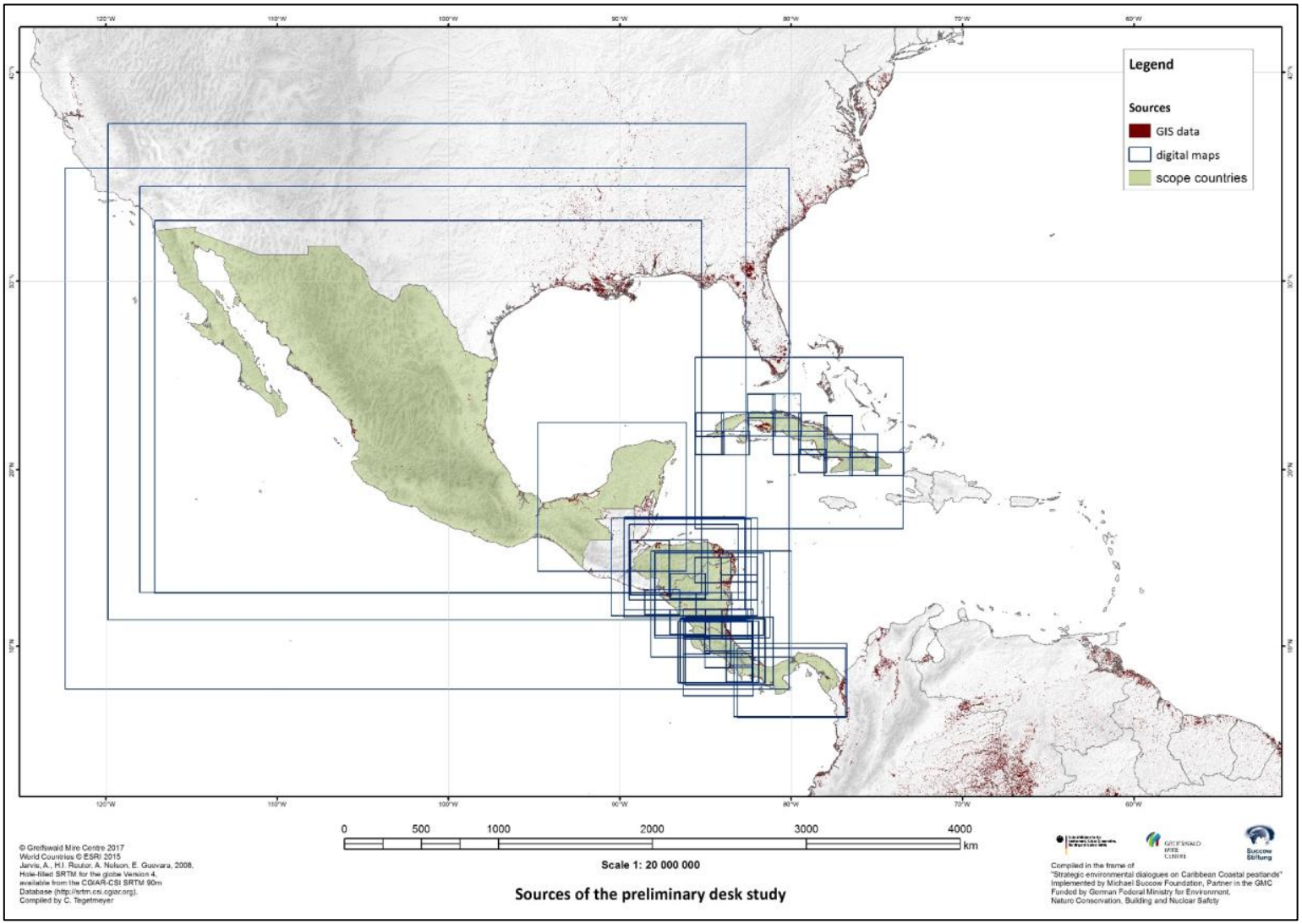


Figure 5: Sources for locating peatlands and organic soils in the Caribbean region included: digital available maps that have been geo-referenced and included in the GIS (preliminary desk study). Blue frames indicate the geographic coverage of each single map. © Michael Succow Foundation/Greifswald Mire Centre (2017).

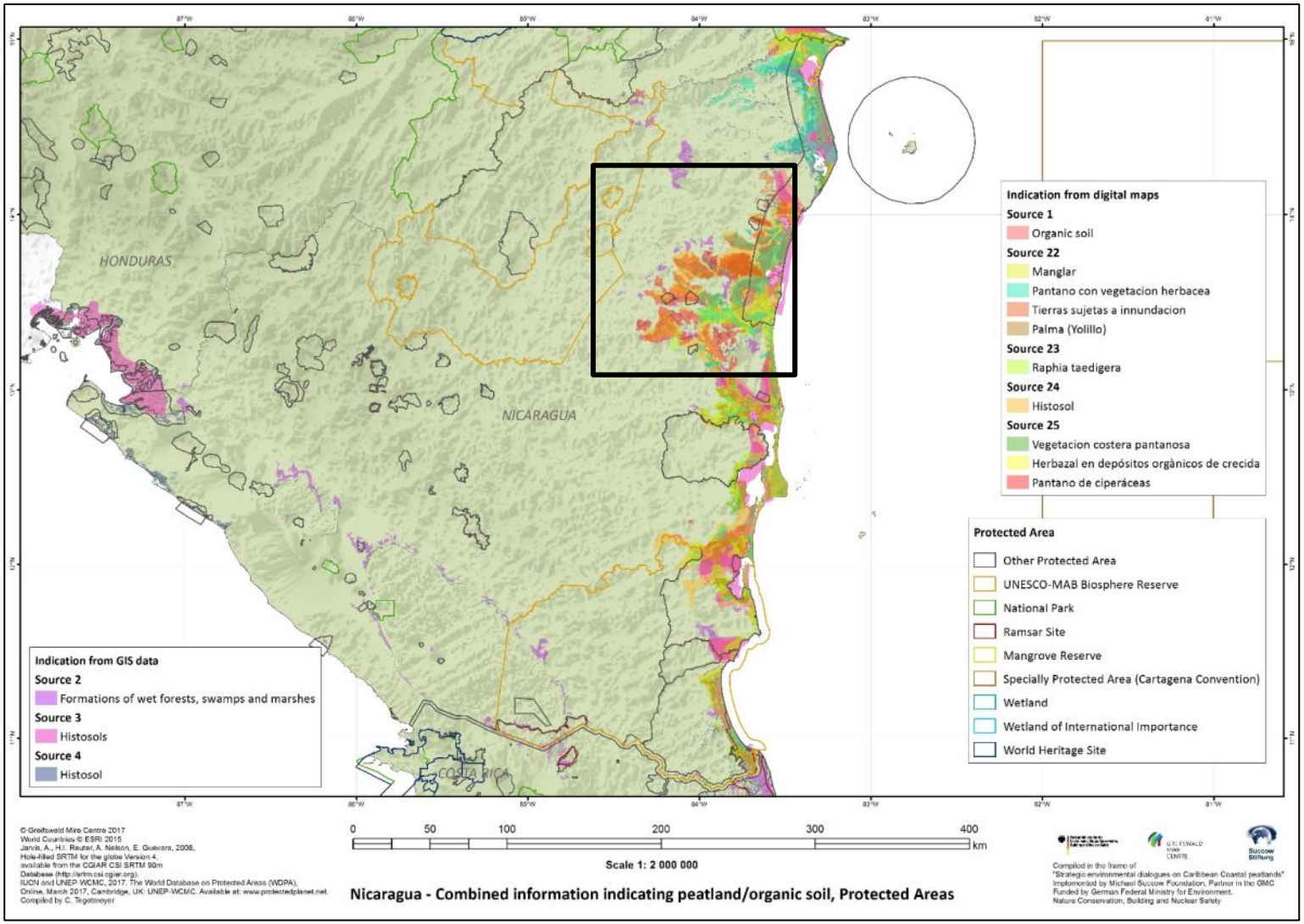


Figure 6: Map showing the transmitted 1 to 1 and superimposed areas from the selected digital maps for Nicaragua in the GIS ('peat', 'specific wetland vegetation', and 'land cover' categories) (references for sources are given below). © Michael Succow Foundation/Greifswald Mire Centre, 2017.

This region south of Puerto Cabezas was chosen as a focal area for refining the peatland probability map. For this process, additional data were assessed and integrated into the GIS, including:

- Satellite images from BING AERIAL (see https://www.bing.com/maps/aerial), that can be included in QGIS using the 'Open Layers Plugin' (Figure 7.A).
- The 'peat' GIS-layer from GLOBAL WETLANDS V2 (CIFOR; cf. Figure 7.B.), available at: https://data.cifor.org/dataset.xhtml?persistentId=doi:10.17528/CIFOR/DATA.00058, and
- The 'MERIT DEM', a Multi-Error-Removed Improved-Terrain DEM (Yamazaki et al. 2017; cf. Figure 7.C), available at: http://hydro.iis.u-tokyo.ac.jp/~yamadai/MERIT_DEM/ (author can be contacted for the download password).

All datasets were integrated and superimposed in the GIS. The data from Global Wetlands (Gumbricht et al. 2017) indicates 'peat' preferably in the brown to black areas of the satellite image (Figure 7.B. and 7.A). Since the CIFOR dataset tends to overestimate peatlands, the MERITT digital elevation model (Yamazaki et al. 2017; Figures 7.C. and 7.D) was used to manually determine and draw the borders of probable peatland areas based on elevation above sea level:

- The digital elevation model shows an interconnected large low lying area between 0 and approximately 3.5 meters above sea level (m.a.s.l). It has been considered as area with 'high probability of lowland peat' (Figure 7.C.).
- Embedded in the potential lowland peatland, there are some dome-shaped areas which elevate between 5 and 8 m.a.s.l. They have been considered as areas with 'high probability of domed peat' (Figure 7.D.).

The GIS work revealed more than 4,000 km² which may host peat or organic soils in the region south of Puerto Cabezas. The field validation of the peatland probability map for such a large area needed an adapted strategy. Using a boat and accessing the validation sites, while following the many rivers in the region, was the best choice. Peat coring was conducted using short transects as outlined in Figure 2B of the Briefing Note G*uidelines for conducting tropical peatland inventories to facilitate their designation as Ramsar Sites*, but with considerable longer distances between the transects, and optionally between the coring sites as well. The amount of coring sites and short transects depend on the size of the Ramsar Site being considered, and the available time and money. If different peatland types can be assumed (as in this example), at least some transects should cross both types. Figure .A. shows a sketch of a minimum coring design to cover most of the area. Short transects may reach at minimum 200 m (or at best 1 km) far from the river bank and may include 3 to 5 coring sites.

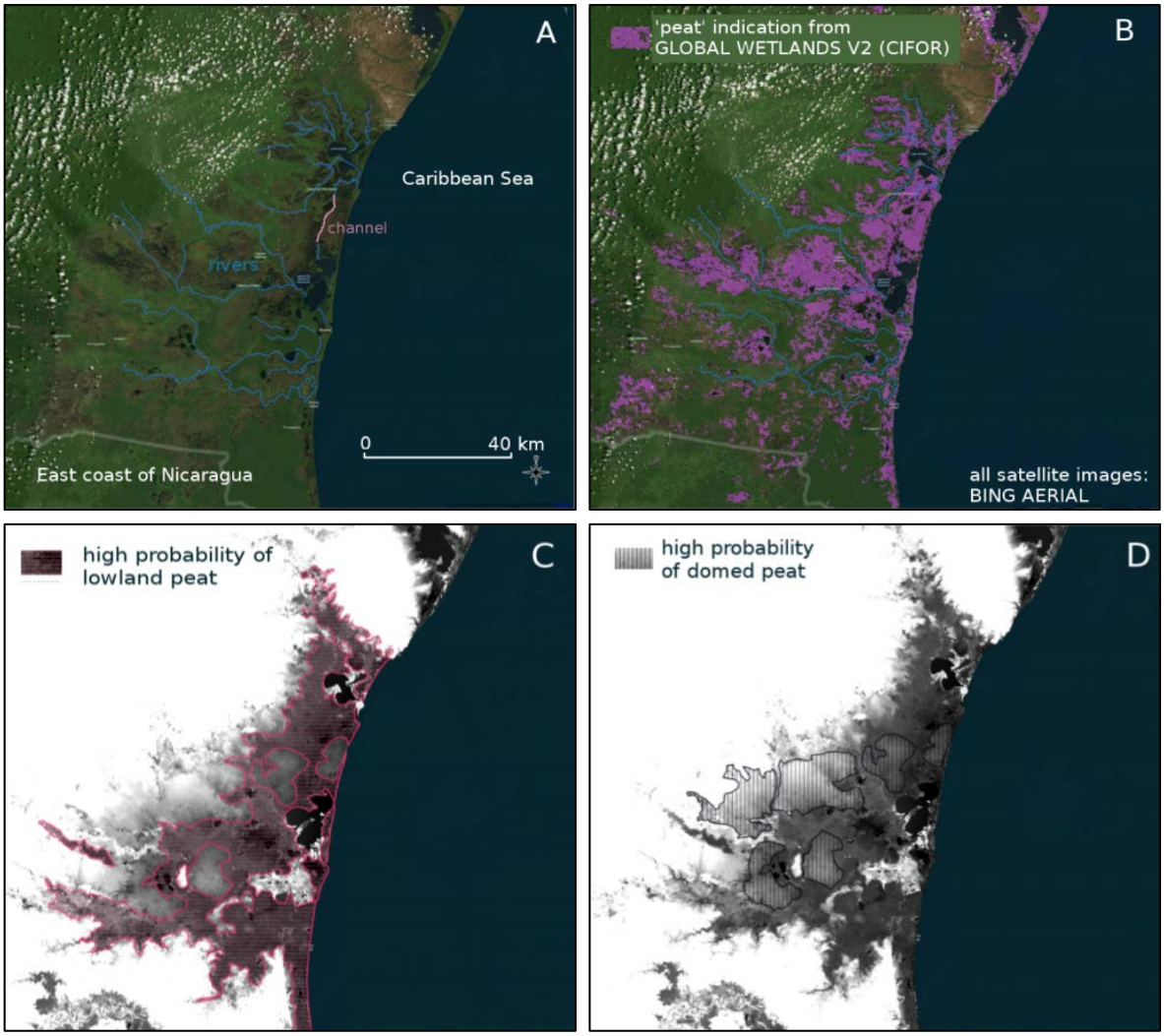


Figure 7: The focal area south of Puerto Cabezas, Nicaragua. A) Bing Aerial satellite view; B) 'peat' indication from Global Wetlands V2 (Gumbricht et al. 2017); C and D) MERIT DEM (Yamazaki et al. 2017): pure black: 0.5 m.a.s.l. sea level, pure white: >20 m.a.s.l., C) areas with high probability of lowland peat, D) high probability of domed peat. © Michael Succow Foundation/Greifswald Mire Centre, 2018.

During a field work campaign in 2017, the presence of peat was validated in the northern part of the peatland probability map between Laguna de Wouhnta and Lake Karatá, as well as north of Lake Karatá (Figure 8.B.)

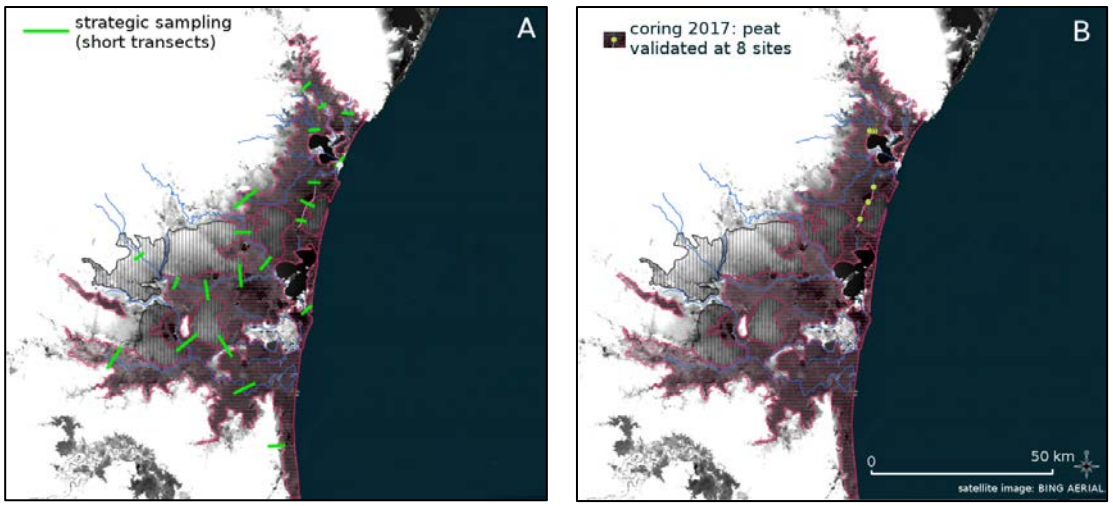


Figure 8: Eight validated peat sites in the assumed 'lowland peatland areas' of the peatland probability map (2 days traveling and coring; field work 2017). © Michael Succow Foundation/Greifswald Mire Centre, 2018.

Sources for developing a peatland probability map for the region south of Puerto Cabezas (Región Autónoma del Atlántico Norte, Nicaragua)

The following digital maps and GIS datasets were used:

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