EARTH OBSERVATION FOR SDG TARGETS AND INDICATORS, LOT-1

SDG 15.2.1 EO PATHFINDER: EO FOR SUSTAINABLE FOREST MANAGEMENT

D1.2 Requirements Baseline

ESA Contract No: 4000139583/22/I-DT
IABG Ref.: TA-B-002505
Date: 2023/06/01
Issue: v1.1

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Document Status

Version	Date	Organisation(s) Author(s)
1.0	2023/04/19	Elke Krätzschmar, Dzhaner Emin, Johannes Albert (IABG) Jonas Franke, Lukas Aschenbrenner (RSS) Henri Giraud (SERTIT) Didier Treinsoutrot (SpaceSeed) Heikki Astola (VTT)
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Document Change Directory

Version	Date	Description	Section/ page
1.1	2023/06/01	Adding executive summary	7/ 75

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

Abbr.	Description
AGB	Above-Ground Biomass
AI	Artificial Intelligence
AOI	Area Of Interest
BFS	Brazilian Forest Service
BMZ (GIZ)	German Federal Ministry for Economic Cooperation and Development
CODS	Centro de Desarrollo Sostenible para América Latina
CONAFLOR	National Forest Commission
CoR	Committee of the Regions
CSD	Commission for Sustainable Developments
DL	Deep Learning
EA	Early Adopter
EO	Earth Observation
EO4SDG	Earth Observation for Sustainable Development
ESA	European Space Agency
FAO	Food and Agriculture Organization of the United Nations
FCH	Forest Characterization
FCM	Forest Condition Monitoring
FCPF	Forest Carbon Partnership Facility
FER	Change in Erosion Risk / Landslide Risk
FHD	Degree of Forest Homogeneity
FLM	Landscape Metrics
FM	Forest Mask
FMP	Forest Management Plans
FNC	Forest Area Net Change Rate
FPA	Forest Protected Areas
FRA	Global Forest Resources Assessment
FSC	Forest Stewardship Council
F-TEP	Forestry Thematic Exploitation Platform (Forestry TEP)
GEDI	Global Ecosystem Dynamic Investigation
GFW	Global Forest Watch

Abbr.	Description
GHG	Green House Gas
GLAD	Global Land Analysis and Discovery
IABG	Industrieanlagen Betriebsgesellschaft mbH
IAEG-SDG	Inter-Agency and Expert Group on SDG Indicators
IBAMA	Brazilian Institute of Environment and Renewable Natural Resources
JRC	Joint Research Center
LULC	Land Use / Land Cover
MARD	Ministry of Agriculture and Rural Development of Vietnam
MDG	Millennium Development Goal
ML	Machine Learning
MMU	Minimum Mapping Unit
MRV	Measurement, Reporting & Verification
NDC	Nationally Determined Contribution
NFI	National Forest Inventory
NFI&S	National forest Inventory and statistic
NFCMP	National Forest Change Monitoring program
NGO	Non-Governmental Organisation
OGC	Open Geospatial Consortium
OSM	OpenStreetMap
PaaS	Platform as a Service
PEFC	Programme for the Endorsement of Forest Certification
REDD+	Reducing Emissions from Deforestation and Forest Degradation and the Role of Conservation, Sustainable Management of Forests and Enhancement of Forest Carbon Stocks in Developing Countries
RSS	Remote Sensing Solutions GmbH
SAR	Synthetic Aperture Radar
SDG	Sustainable Development Goal
SDI	Spatial Data Infrastructure

Abbr.	Description
SDSN	United Nations Sustainable Solutions Network
SFB	Brazilian Forest Service
SFM	Sustainable Forest Management
SRTM	Shuttle Radar Topography Mission
TMF	Tropical Moist Forest
UN	United Nations
UNCED	United Nations Conference on Environment and Development
UNFCCC	United Nations Framework Convention on Climate Change
UNFF	United Nations Forum on Forests
UNISTRA / ICUBE-SERTIT	University of Strasbourg, ICube laboratory, SERTIT platform
UNSPF	United Nations Strategic Plan for Forests
VTT	VTT Technical Research Centre of Finland Ltd

Applicable Documents

Ref.	Title	Version	Date
[AD01]	Ref.: EOP-SD-SOW-0158 Statement of Work ESA Express Procurement - [EXPRO+], Earth Observation for SDG Targets and Indicators Lot-1	1.0	2021/10/14
[AD02]	Ref.: ESA AO/1-10999/21/I-DT, IABG-Ref.: TAE1_21037459_V01 EARTH OBSERVATION FOR SDG TARGETS AND INDICATORS, LOT-1 EXPRO+ SDG 15.2.1 EO Pathfinder - EO for Sustainable Forest Management, Technical Proposal	1.0	2021/12/21

Reference Documents

Ref.	Title	Date
[RD01]	Beck, H. E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., and Wood, E. F.: Present and future Köppen-Geiger climate classification maps at 1-km resolution, Sci Data, 5, https://doi.org/10.1038/sdata.2018.214, 2018.	2023/04/18
[RD02]	Global Forest Resources Assessment 2020, FAO, https://doi.org/10.4060/ca9825en, 2020.	2023/04/18
[RD03]	Transforming our world: the 2030 Agenda for Sustainable Development, 2015 https://documents-dds-ny.un.org/doc/UNDOC/GEN/N15/291/89/PDF/N1529189.pdf?OpenElement	2023/04/18
[RD04]	RESOLUTION A/RES/62/98, GENERAL ASSEMBLY DEFINITION OF SUSTAINABLE FOREST https://www.fao.org/forestry/14717-03d86aa8c1a7426cf69bf9e2f5023bb12.pdf	2023/04/18
[RD05]	FACTSHEETS ON THE 21 SDG INDICATORS UNDER FAO CUSTODIANSHIP https://www.fao.org/3/ca8958en/CA8958EN.pdf	2023/04/18
[RD06]	United Nations Strategic Plan for Forests 2017–2030 https://www.un.org/esa/forests/wp-content/uploads/2016/12/UNSPF_AdvUnedited.pdf	2023/04/18
[RD07]	DIRECTIVE 2009/147/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 November 2009 on the conservation of wild birds https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0147&from=EN	2023/04/18
[RD08]	COUNCIL DIRECTIVE 92 /43 /EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31992L0043&from=en	2023/04/18
[RD09]	DIRECTIVE 2000/60/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 23 October 2000 establishing a framework for Community action in the field of water policy https://eur-lex.europa.eu/resource.html?uri=cellar:5c835afb-2ec6-4577-bdf8-756d3d694eeb.0004.02/DOC_1&format=PDF	2023/04/18
[RD10]	COUNCIL DIRECTIVE 98/83/EC of 3 November 1998 on the quality of water intended for human consumption https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31998L0083&from=EN	2023/04/18

Ref.	Title	Date
[RD11]	COUNCIL DIRECTIVE of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31991L0676&from=EN	2023/04/18
[RD12]	EU Pollinators Initiative https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52018DC0395&from=EN	2023/04/18
[RD13]	REGULATION (EU) 2018/841 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 30 May 2018on the inclusion of greenhouse gas emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework, and amending Regulation (EU) No 525/2013 and Decision No 529/2013/EU https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018R0841&rid=1	2023/04/18
[RD14]	Sustainable development in the European Union Overview of progress towards the SDGs in an EU context 2022 edition https://ec.europa.eu/eurostat/documents/4031688/14665125/KS-06-22-017-EN-N.pdf/8febd4ca-49e4-abd3-23ca-76c48eb4b4e6?t=1653033908879	2023/04/18
[RD15]	Vietnam Forestry Development Strategy https://www.cifor.org/publications/pdf_files/OccPapers/OP-213.pdf	2023/04/18
[RD16]	Vietnam Law on Forestry 2017 https://data.opendevelopmentmekong.net/dataset/54c42bc8-4af9-4b72-8f00-fd33399f420c/resource/0da9b964-93ce-4de4-819f-3b8e6fee376b/download/fn-3-8-13-15-19-33-39-forestry-law-2017.pdf	2023/04/18
[RD17]	VFPDF: Payments for forest environmental services (PFES) in Vietnam: Findings from three years of implementation, Center for International Forestry Research (CIFOR), https://doi.org/10.17528/cifor/005066, 2014.	2023/04/18
[RD18]	Vietnam's Nationally Determined Contribution (NDC) https://unfccc.int/sites/default/files/NDC/2022-11/Viet%20Nam_NDC_2022_Eng.pdf	2023/04/18
[RD19]	Decision 419/2017 on National REDD+ Action Plan (Phase 2) https://www.un-redd.org/sites/default/files/2021-10/National%20REDD%2B%20Action%20programme-NRAP_Vietnam_2017_en.pdf	2023/04/18
[RD20]	Decision 523/QD-TTg 2021 approving the forestry development strategy for the 2021-2030 period https://english.luatvietnam.vn/decision-no-523-qd-ttg-dated-april-01-2021-of-the-prime-minister-approving-vietnams-forestry-development-strategy-for-the-2021-2030-period-with-a-200559-doc1.html#:~:text=-%20By%202030%2C%20all%20forest%20areas%20of%20institutional,of%20the%20forestry%20law%2C%20and%20ensure%20environmental%20security.	2023/04/18
[RD21]	Ex post evaluation report: 2020 Vietnam https://www.kfw-entwicklungsbank.de/PDF/Evaluierung/Ergebnisse-und-Publikationen/PDF-Dokumente-R-Z_EN/Vietnam_Forst_2020_E.pdf	2023/04/18
[RD22]	Sustainable Forest and Forest Land Management in Viet Nam's Ba River Basin Landscape https://www.thegef.org/sites/default/files/web-documents/10539_MFA_PIF_v1.pdf	2023/04/18
[RD23]	German Sustainable Development Strategy https://www.bundesregierung.de/resource/blob/974430/1940716/4bdf89ceea3b1e4367918384b8839a37/2021-07-26-gsds-en-data.pdf?download=1	2023/04/18

Ref.	Title	Date
[RD24]	Sustainable Development in Germany - Indicator Report 2021 https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Nachhaltigkeitsindikatoren/Publikationen/Downloads-Nachhaltigkeit/indikatoren-0230001219004.pdf?__blob=publicationFile	2023/04/18
[RD25]	Forest Strategy 2050 Germany https://www.bmel.de/SharedDocs/Downloads/DE/Broschueren/Waldstrategie2050.pdf?__blob=publicationFile&v=6	2023/04/18
[RD26]	Climate Protection Plan 2050 Germany https://www.bmwk.de/Redaktion/DE/Publikationen/Industrie/klimaschutzplan-2050.pdf?__blob=publicationFile&v=1	2023/04/18
[RD27]	National Strategy on Biodiversity Germany https://www.bmuv.de/fileadmin/Daten_BMU/Pools/Broschueren/nationale_strategie_biologische_vielfalt_2015_bf.pdf	2023/04/18
[RD28]	National Bioeconomy Strategy Germany https://www.bmbf.de/SharedDocs/Publikationen/de/bmbf/7/31576_Nationale_Biooekonomiestrategie_Langfassung.pdf?__blob=publicationFile&v=6	2023/04/18
[RD29]	Integrated Climate Protection Plan Hessen 2025 https://umwelt.hessen.de/sites/umwelt.hessen.de/files/2021-06/integrierter_klimaschutzplan.pdf	2023/04/18
[RD30]	Silva Junior, C. H. L., Pessôa, A. C. M., Carvalho, N. S., Reis, J. B. C., Anderson, L. O., and Aragão, L. E. O. C.: The Brazilian Amazon deforestation rate in 2020 is the greatest of the decade, Nat Ecol Evol, 5, 144–145, https://doi.org/10.1038/s41559-020-01368-x, 2020.	2023/04/18
[RD31]	Harris, N. L., Gibbs, D. A., Baccini, A., Birdsey, R. A., de Bruin, S., Farina, M., Fatoyinbo, L., Hansen, M. C., Herold, M., Houghton, R. A., Potapov, P. V., Suarez, D. R., Roman-Cuesta, R. M., Saatchi, S. S., Slay, C. M., Turubanova, S. A., and Tyukavina, A.: Global maps of twenty-first century forest carbon fluxes, Nat. Clim. Chang., 11, 234–240, https://doi.org/10.1038/s41558-020-00976-6, 2021.	2023/04/18
[RD32]	IMPACTO DA PANDEMIA DE COVID-19 NAS EMISSÕES DE GASES DE EFEITO ESTUFA NO BRASIL https://seeg-br.s3.amazonaws.com/OC_nota_tecnica_FINAL.pdf	2023/04/18
[RD33]	Franchini, M., Mauad, A. C. E., and Viola, E.: De Lula a Bolsonaro: una década de degradación de la gobernanza climática en Brasil, Anal. político, 33, 81–100, https://doi.org/10.15446/anpol.v33n99.90969, 2020.	2023/04/18
[RD34]	Silva Junior, C. H. L., Pessôa, A. C. M., Carvalho, N. S., Reis, J. B. C., Anderson, L. O., and Aragão, L. E. O. C.: The Brazilian Amazon deforestation rate in 2020 is the greatest of the decade, Nat Ecol Evol, 5, 144–145, https://doi.org/10.1038/s41559-020-01368-x, 2020.	2023/04/18
[RD35]	Conservation and sustainable use of natural resources in Ethiopia https://www.giz.de/en/downloads/Factsheet_BFP.pdf	2023/04/18
[RD36]	FRA Report 2020 Vietnam https://www.fao.org/3/cb0089en/cb0089en.pdf	2023/04/19
[RD37]	Talkner, U., Paar, U., Klinck, C., and Bialozyt, R.: Forstliches Umweltmonitoring und Integrierter Klimaschutzplan Hessen 2025, https://doi.org/10.5281/ZENODO.7193740, 11 November 2022.	2023/04/19
[RD38]	FRA Report 2020 Germany https://www.fao.org/3/ca9997en/ca9997en.pdf	2023/04/19

Ref.	Title	Date
[RD39]	Waldzustandsbericht 2022 Hessen https://umwelt.hessen.de/sites/umwelt.hessen.de/files/2022-11/waldzustandsbericht_hessen_2022.pdf	2023/04/19
[RD40]	FRA Report 2020 Brazil https://www.fao.org/3/ca9976en/ca9976en.pdf	2023/04/19
[RD41]	FRA Report 2020 Colombia https://www.fao.org/3/cb0099es/cb0099es.pdf	2023/04/19
[RD42]	Demel T., Mulugeta L., Tesfaye B., Yonas Y., Sisay F., Wubalem T., Yitebetu M., Tesfaye H. and Demeke, N. (2010). Forest Resources and Challenges of Sustainable Forest Management and Conservation in Ethiopia, In Bougers F. and Tennigkeit T. (Eds) Degraded forests in Eastern Africa: management and restoration, Earthscan Publications.	2023/04/19
[RD43]	Garedew E., Sandewall M., Söderberg U. and Campbell B.M. (2009). Land-use and landcover dynamics in the central rift valley of Ethiopia. Environmental Management, 44, 683–694, doi:10.1007/s00267-009-9355-z.	2023/04/19
[RD44]	FAO (2010). Global forest resources assessment 2010. Country Report Ethiopia. FRA2010/065, Rome, 2010. https://www.fao.org/3/i1757e/i1757e.pdf	2023/04/19
[RD45]	Federal Democratic Republic of Ethiopia (FDRE) (2011). Forest Carbon Partnership Facility (FCPF) Readiness Preparation Proposal (R-PP). Final version submitted May 2011. https://www.forestcarbonpartnership.org/system/files/documents/Cameroon%20final%20R-PP-English-January%202013.pdf	2023/04/19
[RD46]	Moges Y., Eshetu Z. and Nune S. (2010). Ethiopian forest resources: current status and future management options in view of access to carbon finances. Literature Review prepared for the Ethiopian Climate Research and Networking and the UNDP. Addis Ababa, October 2010.	2023/04/19
[RD47]	Woody Biomass Inventory and Strategic Planning Project (WBISPP) (2004). Forest Resources of Ethiopia. Addis Ababa, Ethiopia.	2023/04/19
[RD48]	Bucki, M., Cuypers, D., Mayaux, P., Achard, F., Estreguil, C., and Grassi, G.: Assessing REDD+ performance of countries with low monitoring capacities: the matrix approach, Environ. Res. Lett., 7, 014031, https://doi.org/10.1088/1748-9326/7/1/014031, 2012.	2023/04/19
[RD49]	FRA Report 2020 Ethiopia https://www.fao.org/3/ca9991en/ca9991en.pdf	2023/04/19
[RD50]	Federal Democratic Republic of Ethiopia (FDRE) (2011). Ethiopia's Climate-Resilient Green Economy. Green Economy Strategy. Addis Ababa, September 2011. https://gggi.org/wp-content/uploads/2017/11/2015-08-Sectoral-Climate-Resilience-Strategies-for-Ethiopia-1-Agriculture-and-Forestry-Climate-Resilience-Strategy.pdf	2023/04/19
[RD51]	SDG Index country overview Ethiopia https://dashboards.sdgindex.org/static/profiles/pdfs/SDR-2022-ethiopia.pdf	2023/04/19
[RD52]	EARTH OBSERVATION FOR SUSTAINABLE DEVELOPMENT Partnership Report September 2016 https://eo4society.esa.int/wp-content/uploads/2021/11/EOSD_160905-V2-FINAL.pdf	2023/04/19
[RD53]	The CEOS Earth Observation Handbook Special 2018 Edition https://eohandbook.com/sdg/files/CEOS_EOHB_2018_SDG.pdf	2023/04/19
[RD54]	Satellite Environmental Information and Development Assistance: An Analysis of Longer-Term Prospects https://eo4society.esa.int/wp-content/uploads/2020/01/ESA-Space-for-IDA-v3.pdf	2023/04/19

Ref.	Title	Date
[RD55]	EARTH OBSERVATION FOR SDG - Compendium of Earth Observation contributions to the SDG Targets and Indicators, May 202 https://eo4society.esa.int/wp-content/uploads/2021/01/EO_Compendium-for-SDGs.pdf	2023/04/19
[RD56]	Adoption and Impact of Earth Observation for the 2030 Agenda for Sustainable Development https://eo4society.esa.int/wp-content/uploads/2020/07/Caribou-Space_ESA-EO-for-Agenda-2030-v2.pdf	2023/04/19
[RD57]	Nandy, S., Singh, R., Ghosh, S., Watham, T., Kushwaha, S. P. S., Kumar, A. S., and Dadhwal, V. K.: Neural network-based modelling for forest biomass assessment, Carbon Management, 8, 305–317, https://doi.org/10.1080/17583004.2017.1357402, 2017.	2023/04/19
[RD58]	Gomes, V., Queiroz, G., and Ferreira, K.: An Overview of Platforms for Big Earth Observation Data Management and Analysis, Remote Sensing, 12, 1253, https://doi.org/10.3390/rs12081253, 2020.	2023/04/19
[RD59]	Ma, L., Liu, Y., Zhang, X., Ye, Y., Yin, G., and Johnson, B. A.: Deep learning in remote sensing applications: A meta-analysis and review, ISPRS Journal of Photogrammetry and Remote Sensing, 152, 166–177, https://doi.org/10.1016/j.isprsjprs.2019.04.015, 2019.	2023/04/19
[RD60]	Zhu, X. X., Tuia, D., Mou, L., Xia, G.-S., Zhang, L., Xu, F., and Fraundorfer, F.: Deep Learning in Remote Sensing: A Comprehensive Review and List of Resources, IEEE Geosci. Remote Sens. Mag., 5, 8–36, https://doi.org/10.1109/mgrs.2017.2762307, 2017.	2023/04/19
[RD61]	Rodríguez-Veiga, P., Quegan, S., Carreiras, J., Persson, H. J., Fransson, J. E. S., Hoscilo, A., Ziółkowski, D., Stereńczak, K., Lohberger, S., Stängel, M., Berninger, A., Siegert, F., Avitabile, V., Herold, M., Mermoz, S., Bouvet, A., Le Toan, T., Carvalhais, N., Santoro, M., Cartus, O., Rauste, Y., Mathieu, R., Asner, G. P., Thiel, C., Pathe, C., Schmullius, C., Seifert, F. M., Tansey, K., and Balzter, H.: Forest biomass retrieval approaches from earth observation in different biomes, International Journal of Applied Earth Observation and Geoinformation, 77, 53–68, https://doi.org/10.1016/j.jag.2018.12.008, 2019.	2023/04/19
[RD62]	Stehman, S. V.: Basic probability sampling designs for thematic map accuracy assessment, International Journal of Remote Sensing, 20, 2423–2441, https://doi.org/10.1080/014311699212100, 1999.	2023/04/19
[RD63]	S. V. Stehman: "Statistical rigour and practical utility in thematic map accuracy", Photogrammetric Engineering and Remote Sensing, Vol. 67, pp. 727–734, 2001.	2023/04/19
[RD64]	A. Hay: "Sampling designs to test land-use map accuracy", Photogrammetric Engineering and Remote Sensing, Vol. 45, pp. 529-533, 1979.	2023/04/19
[RD65]	R. G. Congalton and K. Green: "Assessing the Accuracy of Remotely Sensed Data: Principles and Practices", Boca Raton, FL: CRC/Lewis Press, 1999.	2023/04/19
[RD66]	Miguel-Ayanz, J. S. and G. S. Biging 1997: "Comparison of single-stage and multi-stage classification approaches for cover type mapping with TM and SPOT data", Remote Sensing of Environment, Volume 59, Issue 1, January 1997, Pages 92-104	2023/04/19
[RD67]	Forest Ecological Stratification in Viet nam https://www.researchgate.net/publication/343380878_Forest_Ecological_Stratification_in_Viet_nam	2023/04/19
[RD68]	FINAL REPORT ON FOREST ECOLOGICAL STRATIFICATION IN VIETNAM https://www.un-redd.org/sites/default/files/2021-10/Final%20submited_Forest%20ecological%20stratification_After%20Aki%20comment_E_VTP%2013102011.pdf	2023/04/19

Ref.	Title	Date
[RD69]	Support to National Assessment and Long Term Monitoring of The Forest and Tree Resources in Vietnam Project no: GCP/GLO/194/MUL/(FIN)-VN Technical Report: Overview of Improved NFIMAP Methodology, Juli 2013 https://www.fao.org/forestry/download/38669-08f5be5e5c51d857a3d1c40d785d079c7.pdf	2023/04/19
[RD70]	Beck, H. E., Zimmermann, N. E., McVicar, T. R., Vergopolan, N., Berg, A., and Wood, E. F.: Publisher Correction: Present and future Köppen-Geiger climate classification maps at 1-km resolution, Sci Data, 7, https://doi.org/10.1038/s41597-020-00616-w, 2020.	2023/04/19
[RD71]	Sannier, C., McRoberts, R. E., and Fichet, L.-V.: Suitability of Global Forest Change data to report forest cover estimates at national level in Gabon, Remote Sensing of Environment, 173, 326–338, https://doi.org/10.1016/j.rse.2015.10.032, 2016.	2023/04/19
[RD72]	Friis I., Demissew S. and van Breugel P. (2010). Atlas of the Potential Vegetation of Ethiopia. Biologiske Skrifter (Biol.Skr.Dan.Vid.Selsk.), 58, pp 307, including 29 map-plates with legends and key.	2023/04/19

Web References

Ref.	URL	Description	Last access
[URL01]	http://www.un-documents.net/a21-11.htm	Agenda 21 United Nations Conference on Environment and Development (UNCED) or Earth Summit, Rio de Janeiro	2023/04/18
[URL02]	https://sustainabledevelopment.un.org/csd.html	Commission on Sustainable Development (CSD)	2023/04/18
[URL03]	https://hlpf.un.org/inputs/united-nations-forum-on-forests-unff-2	United Nations Forum on Forests (UNFF)	2023/04/18
[URL04]	https://www.fao.org/forest-resources-assessment/en/	Global Forest Resources Assessments	2023/04/18
[URL05]	https://www.fao.org/forest-resources-assessment/past-assessments/fra-2020/en/	Global Forest Resources Assessment 2020	2023/04/18
[URL06]	https://www.globalforestwatch.org/	Global Forest Watch	2023/04/18
[URL07]	https://elearning.fao.org/course/view.php?id=446	SDG indicators 15.1.1 and 15.2.1 - Forest area and sustainable forest management	2023/04/18
[URL08]	https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en	Biodiversity strategy for 2030	2023/04/18
[URL09]	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52021DC0572	New EU Forest Strategy for 2030	2023/04/18
[URL10]	https://environment.ec.europa.eu/strategy/biodiversitystrategy2030_en#:~:text=The%20EU%27s%20biodiversity%20strategy%20for,contains%20specific%20actions%20and%20commitments.	Biodiversity strategy for 2030	2023/04/18
[URL11]	https://environment.ec.europa.eu/topics/soil-and-land/soil-strategy_en	Soil strategy for 2030	2023/04/18

Ref.	URL	Description	Last access
[URL12]	https://cinea.ec.europa.eu/programmes/life_en	LIFE Programme	2023/04/18
[URL13]	https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2021%3A400%3AFIN&qid=1620981596225	EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'	2023/04/18
[URL14]	https://agriculture.ec.europa.eu/common-agricultural-policy/cap-overview/cap-glance_en	The common agricultural policy at a glance	2023/04/18
[URL15]	https://agriculture.ec.europa.eu/common-agricultural-policy/financing-cap/cap-funds_en	Common agricultural policy funds	2023/04/18
[URL16]	https://knowsdgs.jrc.ec.europa.eu/intro-policy-mapping	SDG POLICY MAPPING	2023/04/18
[URL17]	https://eu-dashboards.sdgindex.org/	Europe Sustainable Development Report 2022	2023/04/18
[URL18]	https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Land_use_-_cover_area_frame_survey_(LUCAS)	Glossary:Land use - cover area frame survey (LUCAS)	2023/04/18
[URL19]	https://www.eea.europa.eu/data-and-maps/indicators/imperviousness-change-2/assessment	Imperviousness and imperviousness change in Europe	2023/04/18
[URL20]	https://ec.europa.eu/eurostat/cache/metadata/en/env_biodiv_esms.htm	Biodiversity (env_biodiv)	2023/04/18
[URL21]	https://ec.europa.eu/eurostat/web/products-flagship-publications/-/ks-09-22-019	Sustainable development in the European Union – 2022 edition	2023/04/18
[URL22]	https://cor.europa.eu/de/news/Pages/jrc-cor-joins-forces.aspx	Sustainable Development Goals on the ground	2023/04/18
[URL23]	https://english.luatvietnam.vn/decision-no-886-qd-ttg-dated-june-16-2017-of-the-prime-minister-on-approving-target-program-for-sustainable-forestry-development-during-2016-2020-115064-doc1.html	Decision No. 886	2023/04/18
[URL24]	https://english.luatvietnam.vn/law-no-21-2017-qh14-dated-november-14-2017-of-the-national-assembly-on-planning-118858-doc1.html	Planning Law, Law No. 21/2017/QH14	2023/04/18
[URL25]	https://eur-lex.europa.eu/EN/legal-content/summary/voluntary-partnership-agreements-on-forest-law-enforcement-governance-and-trade.html	Voluntary partnership agreements on forest law enforcement, governance and trade	2023/04/18
[URL26]	https://www.dai.com/our-work/projects/vietnam-sustainable-forest-management-activity-sfm	Vietnam—Sustainable Forest Management (SFM) Activity	2023/04/18
[URL27]	https://preferredbynature.org/projects/strengthening-forest-management-practices-vietnam-improved-livelihoods-and-economic	Strengthening forest management practices in Vietnam for improved livelihoods and economic development	2023/04/18
[URL28]	https://www.gfa-group.de/projects/Promotion_of_sustainable_forest_management,_trade_and_marketing_of_important_forest_products,_phase_3_3899566.html	GFA PROJECT	2023/04/18

Ref.	URL	Description	Last access
[URL29]	https://snrd-asia.org/conservation-and-sustainable-use-of-biodiversity-and-ecosystem-services-of-forests-in-vietnam/	Forest Biodiversity and Ecosystem Services in Viet Nam	2023/04/18
[URL30]	https://www.giz.de/en/worldwide/112574.html	Sustainable Forest Management	2023/04/18
[URL31]	http://dns-indikatoren.de/	Indicators of the German Sustainability Strategy	2023/04/18
[URL32]	https://www.bmuv.de/themen/nachhaltigkeit-digitalisierung/nachhaltigkeit/strategie-und-umsetzung/deutsche-nachhaltigkeitsstrategie	German Sustainability Strategy	2023/04/18
[URL33]	https://www.charta-fuer-holz.de/	Charter for Wood 2.0	2023/04/18
[URL34]	https://umwelt.hessen.de/Wald/Klimastabiler-Wald	Forest condition Climate-stable forest	2023/04/18
[URL35]	https://apnews.com/article/climate-caribbean-environment-brazil-jair-bolsonaro-064dbb71f958ed42aac8ad1c932272fb	Brazil withheld deforestation data ‘til COP26’s end	2023/04/18
[URL36]	https://www.statista.com/statistics/1041354/number-wildfires-brazil/#statisticContainer	Number of wildfires in Brazil from 2005 to 2022	2023/04/18
[URL37]	https://ourworldindata.org/drivers-of-deforestation	Drivers of Deforestation	2023/04/18
[URL38]	https://www.forbes.com/sites/davekeating/2018/10/24/the-paris-climate-agreement-survived-trump-can-it-survive-brazils-bolsonaro/	The Paris Climate Agreement Survived Trump. Can It Survive Brazil's Bolsonaro?	2023/04/18
[URL39]	https://forestgovernance.chathamhouse.org/countries/brazil	Forest policy and governance	2023/04/18
[URL40]	https://sdgs.un.org/partnerships/green-legacy-initiative	Green Legacy Initiative	2023/04/18
[URL41]	https://www.efd.gov.et/about/organization-structure/	EFD Organizational Hierarchy	2023/04/18
[URL42]	https://www.giz.de/en/worldwide/94059.html	Forests4Future	2023/04/18
[URL43]	https://www.worldbank.org/en/news/press-release/2023/02/09/world-bank-and-ethiopia-sign-40-million-agreement-to-cut-carbon-emissions-through-sustainable-landscape-management	Cut Carbon Emissions Through Sustainable Landscape Management	2023/04/18
[URL44]	https://www.giz.de/en/worldwide/85075.html	Promoting forest conservation through better marketing of wild coffee	2023/04/18
[URL45]	https://www.giz.de/en/worldwide/38013.html	Protecting nature, preserving biodiversity	2023/04/18
[URL46]	https://mundogeo.com/en/2014/01/31/blackbridge-and-rss-collaborate-with-giz-germany-in-ethiopia/	Ethiopia	2023/04/18
[URL47]	https://www.hessen-forst.de/forstaemter	Unsere 39 hessischen Forstämter	2023/04/19
[URL48]	https://www.hessen-forst.de/ueber-den-landesbetrieb-hessenforst/arbeitsschwerpunkte-und-organigramm	Der Landesbetrieb	2023/04/19
[URL49]	https://www.thuenen.de/de/thuenen-institut/profil	Thünen Institute	2023/04/19

Ref.	URL	Description	Last access
[URL50]	https://www.hessen-forst.de/naturschutz/naturschutzleitlinie	Neue Naturschutz-leitlinie	2023/04/19
[URL51]	https://www.hessen-forst.de/ueber-den-landesbetrieb-hessenforst/pefc-und-fscr-zertifizierung	PEFC- und FSC-Zertifizierung	2023/04/19
[URL52]	https://www.hessen-forst.net/schutzgebiete/	Natura2000	2023/04/19
[URL53]	https://www.hessen-forst.de/naturschutz/naturschutz-im-staatswald	Naturschutz im Staatswald	2023/04/19
[URL54]	https://www.thuenen.de/de/themenfelder/waelder/die-bundeswaldinventur	Bundeswald-inventur	2023/04/19
[URL55]	https://sdg-indikatoren.de/15-1-1/	Indikator 15.1.1	2023/04/19
[URL56]	https://www.gov.br/agricultura/pt-br/	MAPA	2023/04/19
[URL57]	https://www.gov.br/mma/pt-br	MMA	2023/04/19
[URL58]	https://www.gov.br/agricultura/pt-br/assuntos/servico-florestal-brasileiro/	SFB	2023/04/19
[URL59]	https://www.gov.br/ibama/pt-br	Ibama	2023/04/19
[URL60]	https://www.gov.br/icmbio/pt-br	ICMBio	2023/04/19
[URL61]	http://conama.mma.gov.br/	CONAMA	2023/04/19
[URL62]	https://www.gov.br/mma/pt-br/acesso-a-informacao/institucional/quem-e-quem-1/colegiados/comissao-nacional-de-florestas-conaflor	CONAFLOR	2023/04/19
[URL63]	https://www.gov.br/agricultura/pt-br/assuntos/servico-florestal-brasileiro/acesso-a-informacao/gestao-de-florestas-publicas-1/comissao-de-gestao-de-florestas-publicas-cgflop	CGFLOP	2023/04/19
[URL64]	https://snif.florestal.gov.br/en/	NFIS	2023/04/19
[URL65]	https://www.gov.br/agricultura/pt-br/assuntos/servico-florestal-brasileiro/ifn-inventario-florestal-nacional	IFN	2023/04/19
[URL66]	http://siscom.ibama.gov.br/monitora_biomas/	PMDBBS	2023/04/19
[URL67]	http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes	PRODES	2023/04/19
[URL68]	https://www.sosma.org.br/iniciativas/atlas-da-mata-atlantica/	Atlas da Mata Atlântica	2023/04/19
[URL69]	http://redd.mma.gov.br/pt/monitoramento/programa-de-monitoramento-ambiental-dos-biomas-brasileiros	PMABB	2023/04/19
[URL70]	https://queimadas.dgi.inpe.br/queimadas/portal/	Queimadas	2023/04/19
[URL71]	http://www.vae.esa.int/page_documents.php	ESA Value adding element	2023/04/19
[URL72]	https://www.ogc.org/about-ogc/	OGC	2023/04/19
[URL73]	https://docs.ogc.org/bp/20-089r1.html	OGC Best Practice for Earth Observation Application Package	2023/04/19
[URL74]	https://umwelt.hessen.de/sites/umwelt.hessen.de/files/2021-10/waldbesitzarten_2021.jpg	Forstamtsgrenzen und Waldbesitzarten Hessen	2023/04/19
[URL75]	https://en.wikipedia.org/wiki/Indigenous_territory_(Brazil)	Indigenous territory (Brazil)	2023/04/19

Ref.	URL	Description	Last access
[URL76]	https://umwelt.hessen.de/wald	Wir machen den Wald klimastabil	2023/04/19
[URL77]	https://en.wikipedia.org/wiki/Amaz%C3%B4nia_Legal	Amazônia Legal	2023/04/19

1 Scope of the Document

The Requirement Baseline Document is to be the basis for all the activities carried out during the project (Figure 2). The Requirement Baseline Document is structured in the following way.

Chapter 2 provides a review and analysis of the underlying SDG policy framework addressed by the project. First, an overview of the United Nations (UN) Sustainable Development Goals (SDGs) policy framework is given. Then a description of the already established indicators related to Goal 15 Life on Land, Targets 15.1 and 15.2 follow. Finally, a review of key national and supranational SDGs policy frameworks for each of the participating EA's is included. A review of most relevant strategy and guideline papers is performed.

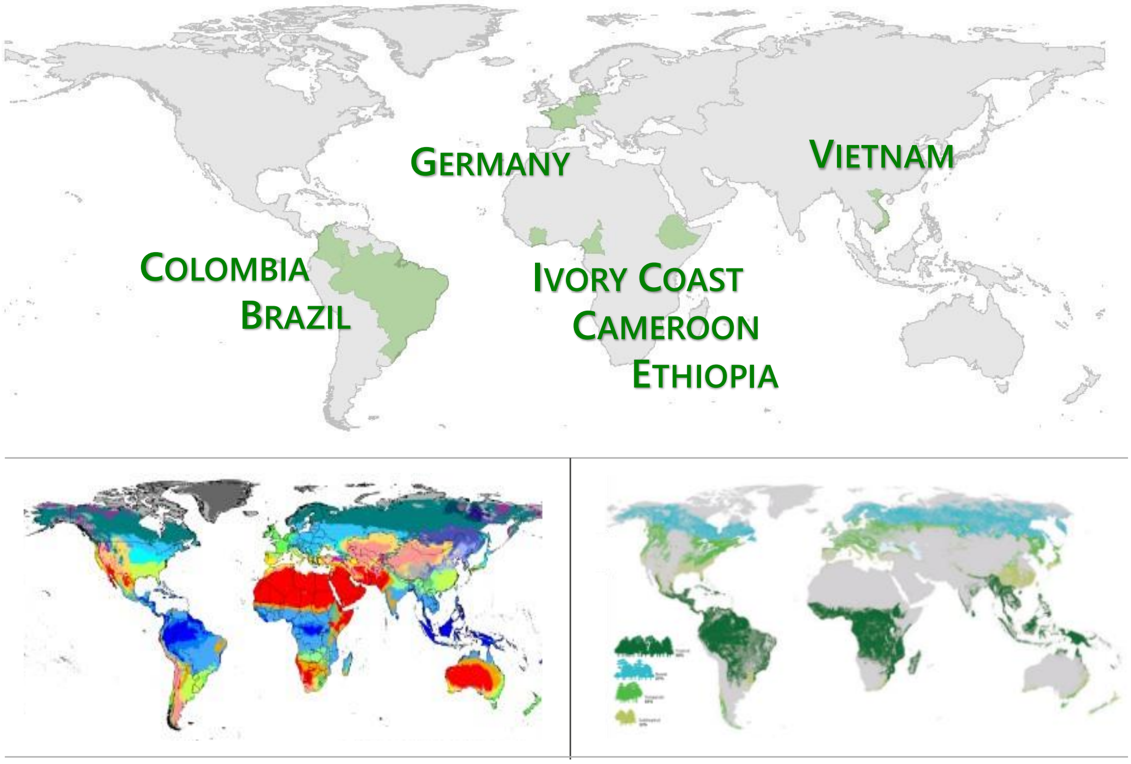

Figure 1: Overview of contacted Early Adopters, distributed over various climatic and vegetation zones [RD01, RD02]

Chapter 3 performs a comprehensive characterisation of the target SDG User Group and of the SDG needs and challenges. A list of relevant Development projects is given for each EA.

Chapter 4 performs an assessment of how EO can help addressing the needs described in previous chapter.

Chapter 5 curates a collection and analysis of the SDG requirements to be addressed by the project, by reviewing the primary requirements in terms of SDG monitoring and reporting needs that the project should primarily address, presents a list of technical requirements for the EO solutions and outlines the identified user requirements as well as the product validation requirements.

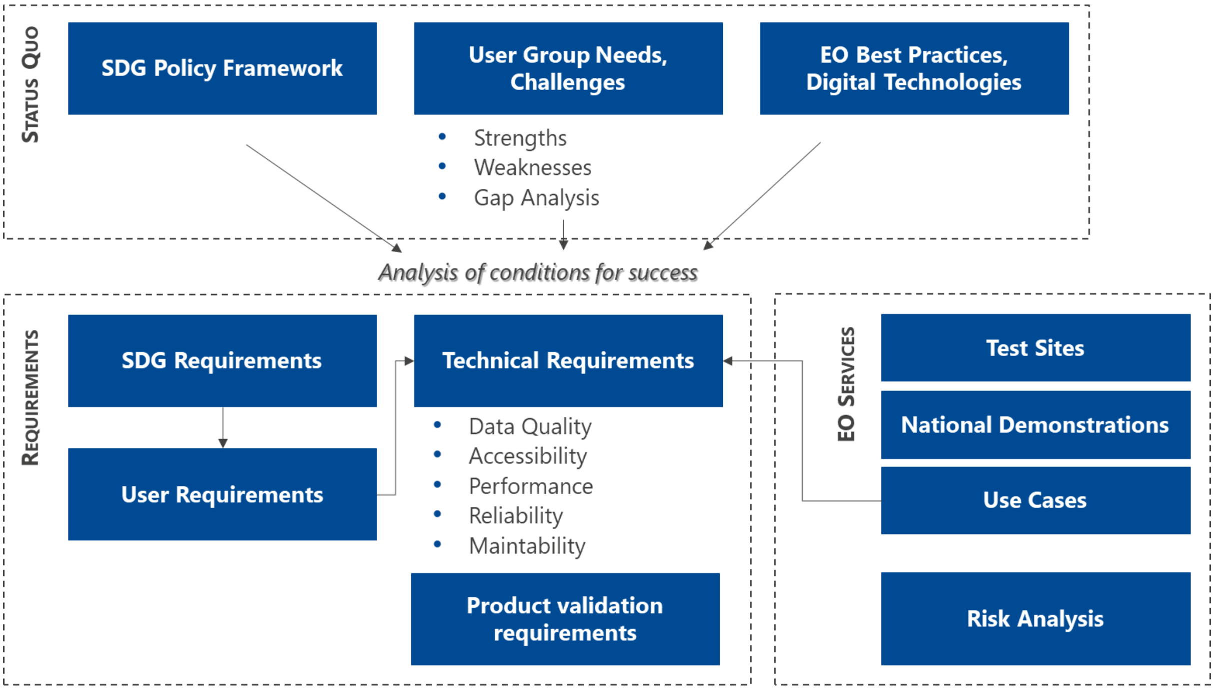

Figure 2: Schematic view of the content of the current document

Chapter 6 describes the specifications of the test sites, national demonstrations and use cases to be conducted to demonstrate the adequacy, robustness, scalability, and usefulness of the proposed solution.

2 Review of SDG Policy Framework

2.1 Supranational

2.1.1 United Nations

The Sustainable Development Goals (SDGs), also known as the Global Goals, were adopted by the United Nations in 2015 as a universal call to action to end poverty, protect the planet, and ensure that by 2030 all people enjoy peace and prosperity. The 2030 Agenda for Sustainable Development [RD03] includes 17 SDGs and 169 associated targets. All 193 United Nations member states have committed to achieve sustainable development across its three dimensions – economic, social, and environmental – in a balanced and integrated manner.

The 17 SDGs are integrated—they recognize that action in one area will affect outcomes in others, and that development must balance social, economic, and environmental sustainability. Goal 15 Life on Land is concerned with the protection, restoration and sustainable use of terrestrial ecosystems, and sustainable forest management. Within Goal 15 Targets 15.1 and 15.2 are directly related to forest ecosystems.

Policy and Strategy at UN Level

Prior to the 2030 Agenda for Sustainable Development, several other documents and initiatives recognized the importance of sustainably using and managing the world's forests (Table 1).

Table 1:. Strategic documents and milestones related to sustainable forest management at UN level

Name	Description	Reference
Agenda 21 United Nations Conference on Environment and Development (UNCED) or Earth Summit, Rio de Janeiro	Chapter 11 "Combating Deforestation" of Agenda 21 is dedicated to sustaining the multiple roles and functions of all types of forests and woodlands, by strengthening forest related national institutions and policies, and enhancing the scope and effectiveness of the management, conservation and use of forests for the production of goods and services.	[URL01]
COMMISSION FOR SUSTAINABLE DEVELOPMENT (CSD)	In paragraph D1 of Chapter 1, the CSD, at its third session, reviewed sectoral clusters such as forests and established the Intergovernmental Panel on Forests (IPF)	[URL02]
UN FORUM ON FORESTS (UNFF)	With Resolution 2000/35, the UN Economic and Social Council (ECOSOC) established the United Nations Forum on Forests (UNFF). A single globally accepted definition of forest was applied for the first time in the Global Forest Resources Assessment in 2000	[URL03]
RESOLUTION A/RES/62/98, GENERAL ASSEMBLY DEFINITION OF SUSTAINABLE FOREST MANAGEMENT (SFM)	SFM has been formally defined as follows: "Dynamic and evolving concept [that] aims to maintain and enhance the economic, social and environmental values of all types of forests, for the benefit of present and future generations".	[RD04]
MILLENNIUM DEVELOPMENT GOAL (MDG) 7 - Environmental sustainability	The UN General Assembly (GA) adopted the UN Millennium Declaration 55/2, setting out and committing to the MDGs, with a deadline of 2015.	[RD05]
2017-2030 | UN STRATEGIC PLAN FOR FORESTS (UNSPF)	The UN Forum on Forests developed the first UN Strategic Plan for Forests, with six voluntary Global Forest Goals, and a framework for action and implementation of international instruments, processes, commitments, and goals for forests.	[RD06]

Indicators and monitoring at UN level

The 2030 Agenda has established a reporting framework with goals, targets and indicators, which relies on inputs from local, national and regional levels. The Food and Agriculture Organization of the United Nations (FAO) is the custodian agency for SDG indicators related to Goal 15 Living on land [RD05].

As a custodian agency, FAO is responsible for:

- developing methodologies to measure progress
- collecting data from countries
- compiling and submitting data and storylines to the United Nations Statistical Division; and
- contributing to developing countries' reporting capacity.

Data collection and reporting for SDG Indicators 15.1.1 and 15.2.1 (Table 2 and Table 3) is conducted through the Global Forest Resources Assessment (FRA). FRA is a well-established programme led by FAO's Forestry Department since 1946 [URL04]. It reports on the extent and changes of the world's forest area, as well as on other variables, including forest ownership and management rights, and legal and institutional frameworks for sustainable forest management. The last FRA Report was published in 2020 [URL05]

The process of reporting (to the FRA Programme) on Indicators 15.1.1 and 15.2.1 involves the following steps:

- National Correspondents (NCs), officially nominated by National Forest authorities, compile and submit official national data to FAO, in coordination with National Statistical Offices.
- The FRA team reviews data and reverts to NCs if necessary.
- Countries validate the data. Once finalized by FAO, the data are sent back to the countries for official validation.
- SDG Indicators 15.1.1 and 15.2.1 are compiled by FAO and submitted to the UN Statistics Division.

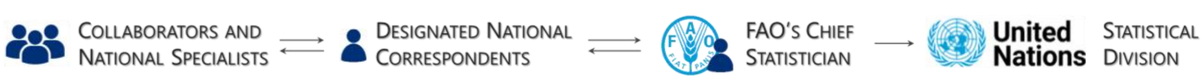

Figure 3: Reporting workflow for Forest Resource Assessment (FRA)

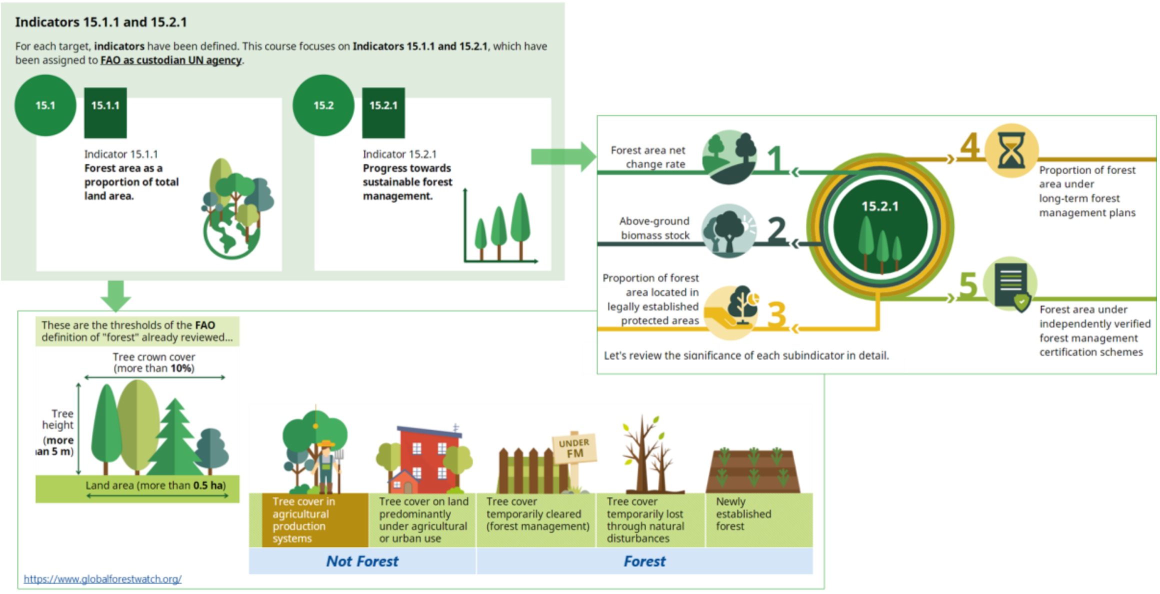

Figure 4: Indicators 15.1.1 and 15.2.1 and the specification of related measures to be addressed [URL06]

Table 2: Target 15.1 and indicator 15.1.1

Name	Definition
Target 15.1	envisions that by 2020 the conservation, restoration and sustainable use of terrestrial and inland freshwater ecosystems and their services, in particular forests, wetlands, mountains, and drylands, in line with obligations under international agreements
Indicator 15.1.1 "Forest Area as a Proportion of Total Land Area"	Approved directly by the Interagency and Expert Group on SDG indicators (IAEG-SDG). This indicator measures the proportion of forest area over total land area. Forest is defined as land spanning more than 0.5 hectares with trees higher than 5 m and a canopy cover of more than 10 %, or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban use
Reporting	Performed through internationally agreed methodology and global reporting rate equal to or higher than 50 %. The main data source for the reporting is the data delivered by Countries to the Global Forest Resources Assessment (FRA). Reported data includes the original data and reference sources and descriptions of how these have been used to estimate the forest area for different points in time.
Constrains	Lack of reliable up-to-date data assessment of forest area is carried out at infrequent intervals in many countries; differences in methodologies and/or definitions over time make hindering comparison of results of different assessments within a given country/territory; Lack of sufficient allocation of needed resources to support the national correspondents.

Table 3: Target 15.2 and indicator 15.2.1

Target 15.2	Postulates the promotion and implementation of sustainable management of all types of forests, halting of deforestation, restoration of degraded forests and the substantial increase of afforestation and reforestation globally.
Indicator 15.2.1 "Progress towards sustainable forest management"	An "index of sustainable forest management" with four sub-indicators can be used as a basic indicator of progress towards sustainable forest management by a country. The four sub-indicators are 1. Annual average percent change in forest area over most recent available 5-year period 2. Annual average percent change in stock of carbon in above ground biomass over most recent available 5-year period 3. Share of forest area whose primary designated function is biodiversity conservation, most recent period 4. Share of forest area under a forest management plan, of which forest area certified under an independent forest management certification scheme, most recent period
Reporting	Countries, through official government-nominated correspondents, provide data for all four elements through established data collection mechanisms, in particular the Forest Resources Assessment (FRA) of FAO. Data on the sub-indicators is available from practically all countries and territories, accompanied by extensive metadata on sources, definitions, conversion from national data to international standards and data quality.
Constrains	The four elements all address major concerns, but, for conceptual and data reasons, some aspects of sustainable forest management are not included, notably jobs and livelihoods revenue and valuation of benefits, forest health and vitality, protection function of forests (soil, water, erosion etc.).

National data provided by the national correspondents and their collaborators is analyzed to derive estimates on the status and trend of the world's forest resources. The results of the analysis as well as the complete set of data collected by FRA 2020 was made available in mid-2020. The sections reporting data relevant for SDG 15 are shown in Table 4.

Table 4: SDG 15 indicators and their FRA 2020 reporting [URL07]

Indicators	FRA reporting
15.1.1 Forest area as a proportion of total land area	1a Extent of forest and other Woodland
15.2.1 Forest area net change rate	1d Annual forest expansion, deforestation and net change
15.2.1 Above-ground biomass stock	2c Biomass stock
15.2.1 Proportion of forest area located in legally established protected areas	3b Forest area within protected areas and forest area with long-term management plans
15.2.1 Proportion of forest area under long-term forest management plans	
15.2.1 Forest area under independently verified forest management certification schemes	Data collected by FAO itself from FSC, PEFC or other schemes

2.1.2 European Union

<u>EU Policies</u>

Numerous EU policies address the 17 SDGs and targets to different extents (Table 5).

Table 5: EU Policies addressing SDG 15

Policy Document	Description	Reference
EU Biodiversity Strategy for 2030	The aims to put Europe's biodiversity on a path to recovery by 2030, by establishing a larger EU-wide network of protected areas on land and at sea, launching a nature restoration plan, and introducing measures to enable the necessary transformative change and to tackle the global biodiversity challenge	[URL08]
EU Birds Directive and the Habitats Directive	Aim to maintain or restore a favorable conservation status of protected habitats and species and safeguard their sustainable use and management. The Birds Directive protects all wild bird species and their habitats. The Habitats Directive introduces similar measures but extends its coverage to more than 1300 other rare, threatened, or endemic species of wild animals and plants. In addition, the Habitats Directives covers 233 natural habitat types.	[RD07] [RD08]
The Water Framework Directive (3)	imposes restrictions on activities that could pollute and damage Europe's freshwater resources. This legislation is complemented by the EU Drinking Water Directive [RD10] and Nitrates Directive [RD11], which also restrict levels of chemicals and minerals in Europe's freshwater resources.	[RD09]
EU Forest Strategy for 2030	sets a vision and concrete actions to improve the quantity and quality of EU forests and strengthen their protection, restoration, and resilience. It includes a roadmap outlining how the Commission plans to achieve the 3 billion additional trees commitment in full respect of ecological principles as set in the EU Biodiversity Strategy for 2030 [URL10]. A high proportion of forests are also covered in the Habitats Directive.	[URL09]
The EU Soil Strategy for 2030	sets out a framework and concrete measures to protect and restore soils and ensure they are used sustainably. The LIFE Programme [URL12] is the key EU's funding instrument for environmental and nature conservation projects. It plays an important role in restoring and safeguarding the condition of terrestrial and freshwater ecosystems.	[URL11]
The Zero Pollution Action Plan for Air, Water and Soil (9)	Maximises synergies with relevant EU policies, such as limiting soil sealing and urban sprawl.	[URL13]
Europe's Common Agricultural Policy (CAP)	sets requirements to protect utilised agricultural areas against erosion and establishes a framework of standards that aim, among other things, to prevent soil erosion. Additional funding is available for farmers through the European Agricultural Fund for Rural Development [URL15] to implement farming practices aimed at addressing biodiversity loss.	[URL14]
The EU Initiative on Pollinators	Puts forward an integrated approach to address the decline in pollinators, including by a more effective use of existing tools and policies.	[RD12]

EU policy and initiatives can be described by two different categories based on their type. The first group contains documents with legal power (Legal Acts) such as Directives, Decisions, Regulations, Recommendations, Declarations, Resolutions. The second group of documents do not have a legal power, but they are used for dissemination of information, e.g. Communications, Staff Working Documents. Large number of policy document related to Goal 15 are produced within.

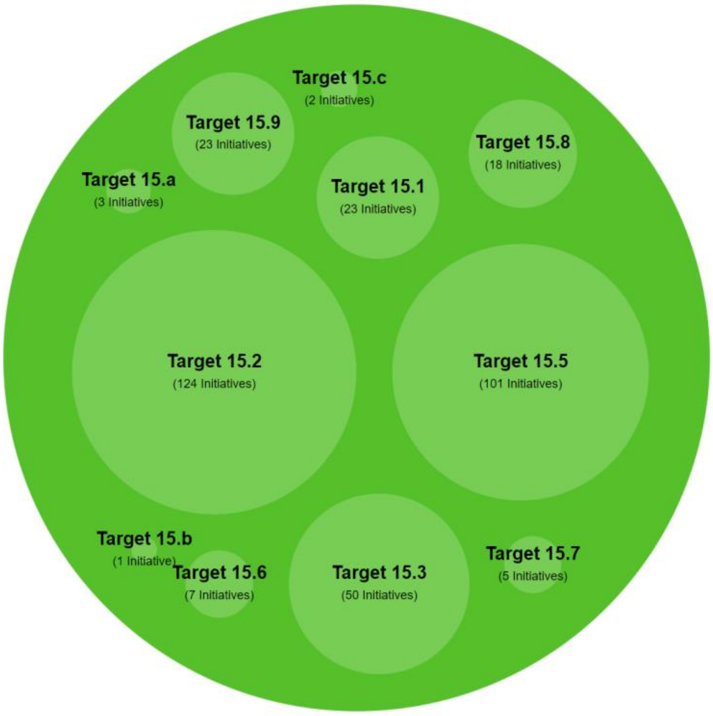

Figure 5: Bubble chart showing the number of legal documents addressing SDG 15 (981 Initiatives) [URL16]

Considerable number of policies address the sustainable development goal 15 Life on Land. For example, Regulation 2018/841 sets out the commitments of Member States for the land use, land use change and forestry ('LULUCF') sector that contribute to achieving the objectives of the Paris Agreement and meeting the greenhouse gas emission reduction target of the Union for the period from 2021 to 2030 [RD13]. This Regulation also lays down the rules for the accounting of emissions and removals from LULUCF and for checking the compliance of Member States with those commitments. Annex 2 of the Regulation defines the parameters for forest area, tree crown cover, and tree height for the member states.

EU indicators

Under the leadership of Eurostat, an EU SDG indicator set for measuring sustainable development in the European Union was developed in 2017. This set measures progress in achieving the SDGs at European level and consists of around 100 indicators structured around the 17 goals of the United Nations 2030 Agenda [URL17].

The set of indicators is revised regularly and is limited to six indicators per sustainability goal to give all goals equal importance and to enable a balanced measurement of the progress of all dimensions of sustainability. Individual indicators are also used to monitor more than one goal, so-called multi-purpose indicators. Tracking progress towards sustainable use of Land (SDG 15) is accomplished through a set of six indicators (Table 6).

Table 6: EU indicators for tracking progress towards SDG 15. Indicators related to forest are highlighted

Name	Description
Share of forest area	Measures the proportion of forest ecosystems in comparison to the total land area. Data used for this indicator is derived from the Land Use and Cover Area frame Survey (LUCAS) [URL18]. The LUCAS land use and land cover classification has been adapted to FAO forest definitions, distinguishing between the categories 'forests' and 'other wooded land'.
Soil sealing index	Estimates the increase in sealed soil surfaces with impervious materials due to development and construction (such as buildings, constructions and laying of completely or partially impermeable

Name	Description
	artificial material, such as asphalt, metal, glass, plastic or concrete). This provides an indication of the rate of soil sealing, which occurs when there is a change in land use towards artificial and urban land use [URL19]. The indicator builds on data from the Imperviousness High Resolution Layer (a product of the Copernicus Land Monitoring Service).
Estimated severe soil erosion by water	Estimates the area potentially affected by severe erosion by water such as rain splash, sheet-wash and rills (soil loss > 10 tonnes/hectare/year). This area is expressed in square kilometres (km^2) and as a percentage of the total non-artificial, erodible area in the country. These numbers are estimated from soil-erosion susceptibility models and should not be taken as measured values.
Terrestrial protected areas	Measures the surface of terrestrial protected areas. The indicator comprises nationally designated protected areas and Natura 2000 sites. A nationally designated area is an area protected by national legislation. The Natura 2000 network comprises both marine and terrestrial protected areas designated under the EU Habitats and Birds Directives with the goal to maintain or restore a favourable conservation status for habitat types and species of EU interest. The EU biodiversity strategy aims to protect at least 30 % of land and sea in Europe including both nationally designated sites and Natura 2000 sites. Data provided by the Member States to the Commission are consolidated at least yearly by the European Environment Agency and the European Topic Centre on Biological Diversity (EEA ETC/BD) and collected by European Commission Directorate-General for the Environment.
Common bird index	This indicator is an index and integrates the abundance and the diversity of a selection of common bird species associated with specific habitats. Rare species are excluded. Three groups of bird species are represented: common farmland species (39 species), common forest species (34 species) and all common bird species (167 species; including farmland and forest species). The indices are presented for EU-aggregates only and with smoothed values. The index draws from data produced by the European Bird Census Council and its Pan-European Common Bird Monitoring Scheme programme. Data coverage has increased from nine to 22 EU Member States over the period 1990 to 2010, with 25 countries covered as of the reference year 2011 [URL20].
Grassland butterfly index	Measures the population trends of 17 butterfly species at EU-level. The index is presented as an EU-aggregate only and with smoothed values. The indicator is based on data from 17 EU Member States (Austria, Belgium, Czechia, Estonia, Finland, France, Germany, Hungary, Ireland, Latvia, Lithuania, Luxembourg, the Netherlands, Romania, Slovenia, Spain, Sweden), but with a limited number of long time-series available. The data are integrated and provided by the European Environment Agency, the European Butterfly Monitoring Scheme partnership and the Assessing Butterflies in Europe (ABLE) project.

The EU SDG indicator set is the basis for Eurostat's annual monitoring report on progress in achieving the SDGs in the EU context. The sixth version of the Monitoring report on progress towards the SDGs in an EU context [URL21] was published at the end of May 2022.

The Eurostat publication "Sustainable development in the European Union - Overview of progress towards in an EU context" [RD14] offers a more concise version, which provides a statistical overview of the current development status of the SDGs in the EU and its member states. Time series for the selected indicators are available for all Member States in the Eurostat database.

The European Committee of the Regions (CoR) cooperates with JRC, European Commission and Parliament to assess Sustainable Development Goals on the ground [URL22]. The pilot project, involving ten regions, has two main objectives:

- Engaging EU regions in the monitoring process of the Sustainable Development Goals (SDGs) – to provide a framework for regional authorities to monitor the SDGs in their territory, and to support and enhance regional statistical capacities in the collection of data, monitoring, and the evaluation process.

- Increase local ownership of SDGs as well as openness and transparency in achieved results – to provide tailored training to regional authorities for the proper collection and analysis of data, to ensure their quality, and make all the data available to the public.

CoR highlights the importance of the involvement of significant data and good practice at local and regional level in the EU SDGs monitoring report.

2.2 National Policies

2.2.1 Vietnam

Forests are at the core of Vietnam's international climate change commitments. Vietnam's Nationally Determined Contribution (NDC) entails an 8% reduction of GHG emissions by 2030 (and 25% with external support) compared to the Business-As-Usual (BAU) scenario and an increase of forest cover to 45%. Commitment to addressing climate change and environmental protection is enshrined in the national constitution and has the support of the Communist Party and the Prime Minister. A short summary and timeline of key strategic and policy documents is shown in Figure 6 and Table 7.

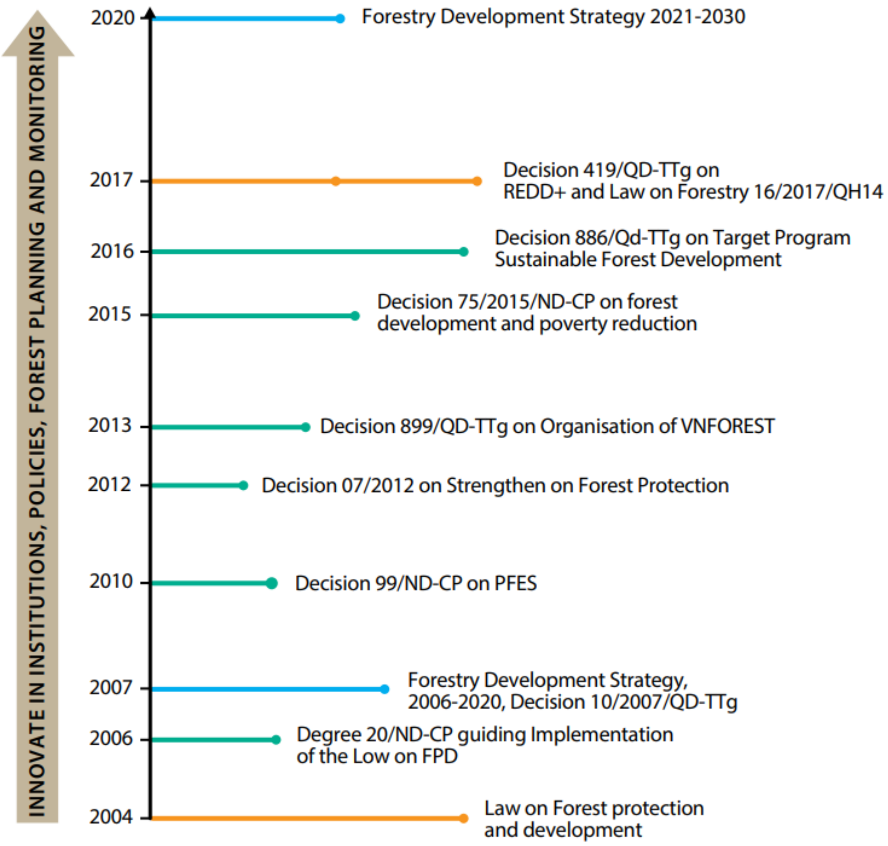

Figure 6: Milestones in Vietnam's forestry policy development [RD15]

Table 7: Vietnam policy documents

Policy document	Description	Source
Prime Minister Decision No 886/2017	Targets for the forest sector were established under Prime Minister Decision No 886/2017 and include targets for the forestry production value (an increase from 5.5 to 6.0 %per year) and the national forest cover (an increase to 42 %, representing a total forest area of 14.4 million ha).	[URL23]
The new Forestry Law (2017)	The new Forestry Law (2017) sets out the future vision for the country's forest sector. It supports: (1) strict management of the conversion of natural forests; (2) logging in natural forests only allowed if there is sustainable forest management (SFM); (3) greater focus on forestry for environmental services; (4) promotion of forestry business, including equitization of SFEs; (5) improved forest tenure to clearly identify forest owners/users; (6) national forestry planning; and (7) control of forest products through Vietnam's Voluntary Partnership Arrangement (VPA).	[RD16]
Planning Law (2017)	The new Planning Law (2017) provides the blueprint for more integrated and sustainable planning. It mandates the integration of climate change and environmental considerations into future planning and will help remove the current overlap of planning activities in many sectors, creating a close connection in planning between the central and grass-roots levels and bringing greater transparency to the overall planning process.	[URL24]
The Vietnam-EU Voluntary Partnership Agreement-Forest Law Enforcement, Governance and Trade (VPA-FLEGT)	The bilateral VPA negotiation with the EU formally started in 2010. The Vietnam-EU Voluntary Partnership Agreement-Forest Law Enforcement, Governance and Trade (VPA-FLEGT) was signed on October 19, 2018, with the aim of tightening controls on forest governance; fighting illegal logging; and promoting trade in verified legal timber products from Vietnam to the EU and other markets. Under the VPA, the Vietnamese government is also committed to developing the Vietnam Timber Legality Assurance System (VNTLAS).	[URL25]
The Vietnam Payment for Forest Environmental Services (PFES)	The Vietnam Payment for Forest Environmental Services (PFES) scheme has been operational since 2010 and is now the main source of finance. The PFES system is implemented by provinces, which have some flexibility in defining how it is carried out.	[RD17]
Vietnam's Nationally Determined Contribution (NDC)	Vietnam's Nationally Determined Contribution (NDC) estimated that forestland would be a major sink for carbon, accounting for 22.5 million tons of carbon dioxide equivalent (CO2e) reductions in 2010, 50.4 million tons of CO2e reductions in 2020, and 53.1 million tons of CO2e reductions in 2030.	[RD18]
Decision 419/2017 on National REDD+ Action Plan (Phase 2)	Decision 419/2017 on National REDD+ Action Plan (Phase 2) was approved by the Prime Minister in April 2017. The Decision identified 11 work packages covering forest and nonforest interventions to address the key elements of REDD+.	[RD19]

National Forest Strategy

Vietnam adopted a national "Vietnam Forest Development Strategy 2006–2020" (VFDS) [RD20] approved by the Prime Minister in Decision No. 18/2007/QD-TTg with the overall goal of:

> "Establishing, managing, protecting, sustainable development and use of 16.24 million ha of land planned for forestry; increase the percentage of forested land to 42–43% by 2010 and 47% by 2020; ensure broad participation of economic sectors and social organisations in forestry development to contribute increasingly to socio-economic development, protect ecological environment, conserve biodiversity and provide environmental services, contribute to poverty reduction, improve living standards for rural mountainous people and maintain national security and defense."

The strategic plan provided four strategic directions and seven implementation solutions through five programs.

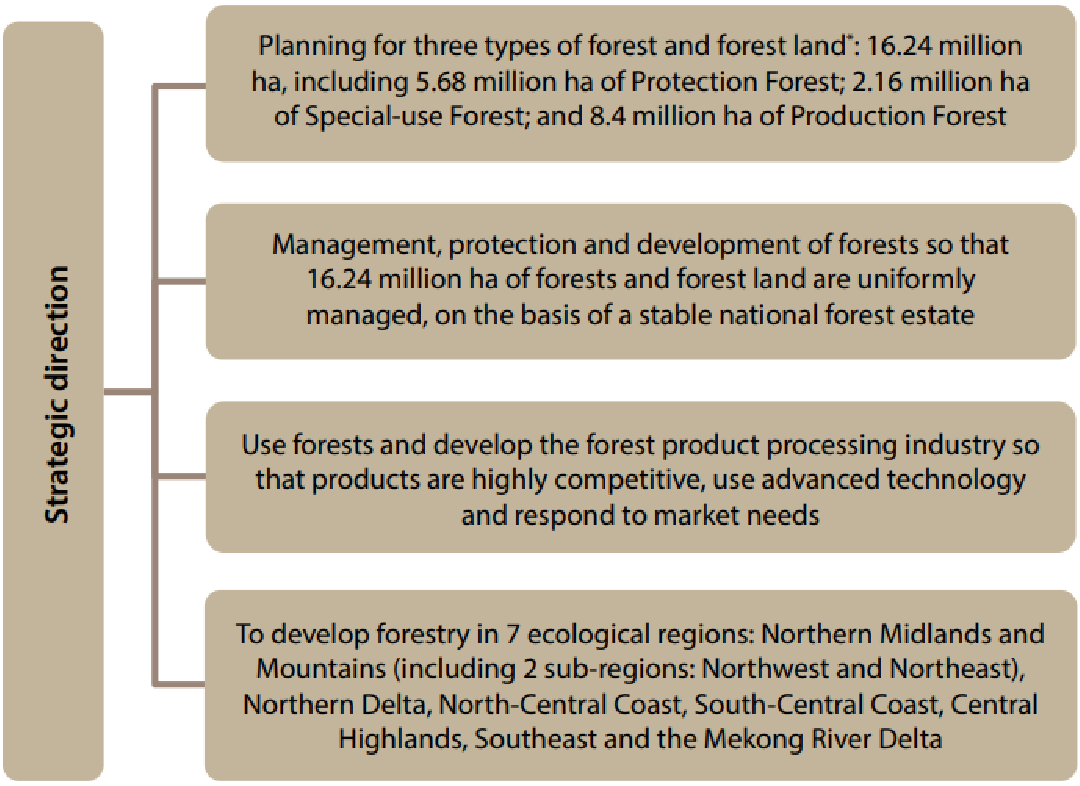

Figure 7: Four strategic directions enshrined in the "Vietnam Forest Development Strategy" [URL15]

National Indicators

VFDS 2006–2020 was formulated with the active and effective support of many international organisations through the Forest Sector Support Partnership (FSSP) that provided comprehensive direction for development of the forestry sector. Since 2004, to monitor the sector, the FSSP has supported MARD to develop a Forestry Sector Monitoring Information System (FORMIS) with a set of 36 indicators. In 2006, this set of indicators was revised and supplemented to monitor and evaluate implementation of VFDS 2006–2020; the revised version included 72 indicators, of which 15 were key indicators, but at that time there was no data available for the purposes of monitoring and evaluation; these were thus named "future indicators". The indicator set is divided into four groups: i) the overarching goal, with four indicators; ii) specific economic, social, and environmental targets, with 13 indicators; iii) program-related performance targets, with 47 indicators; and iv) inputs, including 8 indicators.

Table 8: Economic Indicators in Vietnam National Forest Strategy [RD15]

No	Objectives	2006	VFDS target (Dec 18)	Adjusted target	Implementation results 2020	Evaluation	
						Compared with VFDS target	Compared with adjusted target
1	Growth rate of forestry production (%/year)	1.9	3.5–4.0	5.5–6.0[1]	4.87	Achieved	Achieved
2	Rate of forestry GDP/national GDP (%)	<1	2–3		0.65	Not achieved	Not achieved
3	Establishing, managing, protecting, developing and sustainably using three types of forests (ha)	12,529	16,240[2]	14,400[3]	14,609	Not achieved	Achieved
4	Production forest area with SFM certification		30%	0.1 million ha/year[4]	269,163 ha	Not achieved [5]	Not achieved
5	Afforestation (million ha)		1.5	0.125[6]	1.233	Not achieved [7]	98.6% achieved
6	Reforestation after harvesting (million ha/year)	0.184	0.3	0.135[8]	0.235	Not achieved [9]	Achieved
7	Zoning for natural regeneration (million ha/year)		0.8	0.36[10]	0.34	Not achieved [11]	Not achieved
8	Scattered tree planting (million trees/ year)	202.5	200	50[12 13]	63	Not achieved [14]	Achieved
9	Domestic wood production (million m3/year)	3.01	20–24		20.5	Achieved [15]	Achieved
9a	Domestic large-diameter timber logging (million m3)		10		3–4	Not achieved	Not achieved
10	Firewood for rural areas (million m3/year)	26.07	25–26		19.5	Not achieved	Not achieved
11	Export of forest products (billion USD)	2.17	7.8	8.0–8.5[16]	12.0	Reached[17]	Reached
11a	Export of wood products (billion USD)	1.94	7.0		11.3	Reached [18]	Reached
11b	Export of non-timber forest products (billion USD)	0.23	0.8		0.9	Reached	Reached
12	Revenue from FES (billion USD)		2.0		0.728	Not achieved	Not achieved

Table 9: Environmental Indicators from Vietnam National Forest Strategy [RD15]

No.	Objective	2006	VFDS target (Dec '18)	Adjusted target	Implementation results 2020	Evaluation	
						Compared with VFDS target	Compared with adjusted target
1	Management, protection and development of three types of forests (million ha)	12.5	16.24	14.4[1]	14.6[2]	not achieved	achieved
2	Forest coverage (%)	37.7	47	42[3] 44–45[4]	42	not achieved	achieved
3	Planting of protection and special-use forests (million ha)		0.25	0.075 (2016–2020)[5]	0.694[6]	achieved	achieved
4	Minimize violations of the law on forest protection and development (%)	38.534	Reduce by 80%	Reduce by 30–35% by 2011–2015[7]	10.731	not achieved	achieved

Development Projects and Cooperation

A lost of recent development projects and international cooperations in the area of sustainable forest development are listed in Table 10.

Table 10: List of recent development projects related to Forest Sustainable Development in Vietnam

Project	Link
Vietnam-Sustainable Forest Management (SFM) Activity Country: Vietnam Funded by: United States Agency for International Development (USAID)	[URL26]
KfW4: 199865676 Reforestation in Thanh Hoa and Nghe An (IV) (+ complementary measure 2001 70 225); **KfW6: 200065912 Forest rehabilitation and sustainable forest management in Quang Nam, Quang Ngai, Binh Dinh, Phu Yen (Reforestation VI)*** Implementing agency: Ministry for Agriculture and Rural Development (MARD)	[RD21]
Strengthening Forest management practices in Vietnam for improved livelihoods and economic development Partners: Sustainable Forest Management (SFM) & Government of Vietnam (GVN) Funded by: United States Agency for International Development (USAID) Budget: USD 2,500,915 Duration: Aug 2020 - 2025	[URL27]
Promotion of Sustainable Forest Management, Trade and Marketing Of Important Forest Products, Phase 3 Commission Agency: BMZ (GIZ) Duration: 2011 - 2014	[URL28]
Conservation and Sustainable Use of Forest Biodiversity and Ecosystem Services in Vietnam Commission Agency: BMZ (GIZ) Duration: 01 Jan 2018 - 31 Dec 2021	[URL29]
Upscaling Sustainable Forest Management and Certification in Vietnam Commissioned by: German Federal Ministry for Economic Cooperation and Development (BMZ/GIZ) Lead executing agency: Ministry of Agriculture and Rural Development (MARD) Overall term: 2021 to 2024	[URL30]
Sustainable Forest and Forest Land Management in Vietnam's Ba River Basin Landscape Agency(ies): UNDP Other Executing Partner(s) Executing Partner Type: Forest Inventory and Planning Institute (FIPI) of Ministry of Agriculture and Rural Development (MARD) Overall term: 2022 to 2026 The project is very important in supporting Vietnam to fulfill its commitments to the UN Convention on Biological Diversity (CBD) and the UN Convention to Combat Desertification (UNCCD) as well as implement its national strategies and priorities on forestry and biodiversity conservation, particularly the Vietnam Forest Development Strategy during 2021-2030 with a vision to 2050.	[RD22]

2.2.2 Germany (Federal state of Hessen)

National Sustainability Strategy

The Federal Government of Germany has committed itself to implementing the goals of the 2030 Agenda at national level. This resulted in the revision of the national sustainability strategy by the federal government and its adoption in January 2017 and update in 2021 [RD23]. The German Sustainable Development Strategy is the key instrument for strategically guiding and implementing sustainability in Germany. It is aligned with the 2030 UN-Agenda and its 17 Sustainable Development Goals (SDGs). The German Strategy contains 75 indicators which are published by Germany's Federal Statistical Office. The indicator report of the Federal Statistical Office includes the indicators for measuring the achievement of the goals of the German sustainability strategy. The information is also available on the online platform "Sustainable Development in Germany" [URL31] and in the report "Sustainable Development in Germany" [RD24]. Within the German Strategy, SDG 15 is covered by four indicators (Table 11). A complete further development of the strategy is scheduled for 2023/2024.

Table 11: Indicators pertaining to SDG 15 adopted by the German National Strategy on Sustainable Development

Indicator	Description
15.1 Biodiversity and landscape quality	an indicator tracking populations of representative bird species in different main habitats and landscape types in the biodiversity and landscape quality category
15.2 Eutrophication of Ecosystems	an indicator measuring ecosystems in which critical loads for eutrophication due to nitrogen input are exceeded under the heading protecting ecosystems, conserving ecosystem services and preserving habitats
15.3a, b Preservation or restoration of forests under REDD+ 15.3.a	Indicators on the REDD+ rulebook and international soil protection depicting the preservation or restoration of forests under REDD+ (reducing emissions from deforestation and forest degradation) and international soil protection. The indicator shows the results-based payments by Germany to developing and emerging countries for the verified preservation or restoration of forests under the REDD+ rulebook (Reducing Emissions from Deforestation and Forest Degradation). REDD+ is an international concept which financially rewards governments and local communities in developing countries for reducing deforestation and thereby demonstrably cutting emissions. Contributions are paid in line with the scale of the emissions reduction measured or the amount of additional carbon sequestered.
15.3. b	The indicator covers Germany's gross bilateral development expenditure in connection with the implementation of the UN Convention to Combat Desertification in developing and emerging countries.

<u>National Forest Strategy</u>

The current National Forest Strategy 2050 for Germany is a follow-up to the original Forest Strategy of 2011 [RD25]. It intersects with numerous other national concepts and strategies of the German Federal Government, such as the Sustainability Strategy [URL32], the Climate Protection Plan 2050 [RD26], the National Strategy on Biological Diversity [RD27], the National Bioeconomy Strategy [RD28] and the Charter for Wood 2.0 [URL33]. Coordinated with each other, they jointly support the course for sustainable development in Germany. In the context of climate change, forests should be sustainably preserved because of their economic benefits, their importance for the environment and their protective and recreational function. To accomplish this, the aim is to achieve forest management that is as close to nature as possible and provides all ecosystem services. In this way, the guiding principle of the Forest Strategy supports the Sustainable Development Goal 15 of the UN. In order to maintain sufficient flexibility with regard to future developments, the guidelines for 2050 were divided into the following ten fields of action:

- Climate protection and adaptation to climate change
- Biodiversity and forest nature conservation
- Wood production and use

- Recreation, sport and health
- Soil and water
- Forest development, sustainable management and hunting
- Forest ownership and new value creation
- Forestry, digitalisation and technology
- Research and development
- Communication and information

59 milestones are derived from these ten fields of action and form concrete intermediate targets up to the year 2030.

Hessens Policies

The Hessian state government adopted an immediate program to preserve and protect the Hessian forests in 2019. The plan is structured in 12 points to protect the forests in the face of climate change [URL34]. One focus is the processing of the damaged wood caused by the extreme weather events of the past two years (Table 12).

Table 12: The 12-point plan to improve the forest conditions in Hessen

Point	Action	Description
1	Support for forest owners in removing forest damage	Around 50 million € in federal and state funds are available for points 1 and 2 until 2023.
2	Support for the reforestation of climate-adapted forests and for traffic protection	Around 50 million € in federal and state funds are available for points 1 and 2 until 2023.
3	Assistance with traffic safety obligations	Now part of the extreme weather guideline. For the original hardship regulation, 2 million € were provided, which are now included in the extreme weather directive.
4	Relief for the municipalities through a fee moratorium	Annual reforestation cost increases are suspended. HessenForst charges forestry costs for the care of the municipal forest; the planned increases up to 2023 were waived.
5	Simplification of forest funding procedures	The EU de minimis regulation for subsidies under the extreme weather directive is no longer applicable. This regulation stated that a forestry company may not receive more than 200,000 € in aid within three tax years.
6	Support for the establishment of timber marketing organisations	The state encourages municipal and private forest owners to set up their own wood marketing organisations.
7	Reforestation of the Hessian forest and intensification of research	In 2019, the specialist symposium "Tree species in the Hessian forest of the future" took place, at which scientists and associations discussed the status of research and research approaches. A reforestation decree for the Hessian state forest was issued in February 2020
8	State Forest Program "Mixed Forest for Tomorrow"	HessenForst has been receiving 30 million € annually since 2020 for the elimination of forest damage and for reforestation.
9	Protection of reforestation from game damage	A corresponding hoofed game guideline was issued in 2019. April hunting for roe deer, red deer and other hoofed game has also been permitted since 2020.

Point	Action	Description
10	Discounts on the taxation of income from extraordinary timber use	The Hessian tax authorities decide quickly on applications for equitable relief (including tax deferrals) made with reference to forest damage.
11	Adaptation of staffing	The HessenForst personnel concept will be changed in line with the results of the evaluation and against the background of the current challenges. The job cuts planned by 2025 will be stopped, new target figures with more staff on the site are planned.
12	Call on the federal government to modernise the forest damage compensation act	The state government has asked the federal government to modernize the Forest Damage Compensation Act with regard to climate change and the resulting (major) damage events.

The Integrated Climate Protection Plan Hessen 2025 is looking for solutions to protect the climate and possibilities for adaptation in all areas of life [RD25]. The plan focuses on analysis of the situation, on Implementation of measures and on uniform long-term observation (monitoring) of further developments in Hessen.

2.2.3 Brazil

Brazil is home to one of the largest forest sinks in the world, the Amazon rainforest, and made notable progress against illegal deforestation in the late 2000s. In 2012, deforestation rates were down by 84% compared to the peak year of 2004 [RD30]. Since then, however, the deforestation rate has risen again: in the period from August 2020 to July 2021 deforestation has increased by 22% compared to the same period of the previous year and is the highest since 15 years [URL35].

Almost 223,000 wildfire outbreaks were identified in Brazil in 2020, the highest figure reported in a single decade [URL36]. At the current deforestation rate, the Amazon is on the verge of turning from a net carbon sink into a source [RD31]. The continued roll-back of forest protection policies and the expansion of pasture for beef production, croplands for soy and palm oil, and increasingly conversion of primary forest to tree plantations for paper and pulp have been the key drivers of this. Three-quarters of tropical deforestation in Brazil is driven by cattle ranching [URL37]. Most of the country's GHG emissions are the result of activities in the agriculture (28%), land-use change and the forestry sector (46%), which together accounted for three-quarters of Brazil's total GHG emissions in 2020 [RD32].

Brazil was the first signatory of the 1992 United Nations Framework Convention on Climate Change (UNFCCC), which took place in Rio de Janeiro, and a forerunner in global climate politics in the following two decades [RD33].

A 2007 Decree established the governance structure that developed the National Plan on Climate Change. The Climate Plan provided a comprehensive framework to combat climate change. In the same year, the Federal Government established the Inter-ministerial Committee on Climate Change (CIM). Its overall goal was to support coordination of policy actions between line ministries (Decree No 6.263, 2007). Its mandate was later expanded to also coordinate climate change-related activities and to support the implementation of Brazil's NDC (Decree No 9.073, 2017). Since then, the country has introduced a large number of climate-related laws.

In 2009, the Federal Government announced the National Policy on Climate Change, a voluntary mitigation commitment to reduce emissions by 36-39% by 2020 below 2010 levels, in preparation for the Conference of the Parties (COP) in Copenhagen that same year. Further relevant laws and plans that have been introduced in the past include the 2012 Brazilian Forestry Code, which established rules on the protection of vegetation and forests, and the 2018 Environmental Criminal and Administrative Offences Act, which defined sanctions derived from activities harmful to the environment.

In 2016, the government released the National Adaptation Plan, which guides initiatives for the management and reduction of long-term climate risks. On the sectoral level, there are a number of plans that set out mitigation and adaptation measures.

In the last decade, and especially in recent years, Brazil's role in climate policy has changed significantly. Since 2012, the Rousseff and Temer administrations have weakened environmental policies. With Jair Bolsonaro's election in 2018, whose election promises included withdrawing Brazil from the Paris Agreement, the situation has worsened [URL38].

While Brazil is still a party to the Paris Agreement, its environmental regulations have been weakened and deforestation rates in the Amazon increased considerably. The Bolsonaro administration has also substantially weakened the power and budget of the Ministry of Environment [RD34]. In 2021, he approved a total budget cut of 24% compared to 2020 [URL36].

In December 2020, the Brazilian government submitted an updated Nationally Determined Contribution (NDC) to the UNFCCC. Like the previous 2016 NDC, the updated NDC set the target of a 37% GHG reduction by 2025 and a 43% GHG reduction by 2030, below a 2005 baseline level. While the targets remained unchanged on paper, the emissions in 2005 increased as a result of an emissions inventory revision. This effectively weakened the targets presented under the updated NDC.

After considerable changes at the beginning of this century, Brazil has made limited improvements to forest governance since 2013. Between 2013 and 2018, high-level commitment to forest conservation was reduced but new public procurement regulations have embraced sustainability and transparency measures and controlling systems have been improved.

Brazil continues to stand out due to its legal framework and remote monitoring technology which have served as examples for other countries. The recently launched instruments – National System for the Control of the Origin of Forestry Products (SINAFLOR) and the real-time deforestation detection system DETER-B – and the Brazilian Institute of Environment and Renewable Natural Resources' (IBAMA's) federal plan on open data promise improvements in the transparency of tracking illegal logging activity although these initiatives have yet to be fully implemented [URL39].

The following Table 13 provides an overview of key environmental laws and regulations in Brazil.

Table 13: Key environmental laws and regulations in Brazil

Legislation	Comments
Federal Law No. 6,938/1981 National Environmental Policy Act (PNMA)	This law establishes Brazil's National Environmental Policy, its purposes and mechanisms, sets up the National Environmental System (SISNAMA) and establishes the Environmental Defence Registry. The National Environmental Policy aims at preserving, improving and recovering environmental quality in the country.
Federal Law No. 9,605/1998 Environmental Criminal and Administrative Offences	This law defines criminal and administrative sanctions derived from conducts and activities harmful to the environment.
Federal Law No. 12,187/2009 National Policy on Climate Change (PNMC)	This law institutes the National Policy on Climate Change with the view of providing an institutional structure and resources dedicated to the protection of the environment from the risks of climate change. The Policy also includes within the main guidelines all United Nations' provisions on Climate Change as well as those of Kyoto Protocol. The Senate approved Bill No 6539/2019 in November 2021 amending Law 12.187/2009, to include the updated commitments made by Brazil under the Paris Agreement.

In addition to these key environmental laws, other major legislative texts are specifically dedicated to forestry (Table 14).

Table 14: Key laws and regulations in Brazil addressing forestry

Legislation	Comments
Federal Constitution 1988	Article 225 of the Constitution provides the main framework and provisions for environmental protection in Brazil.
Federal Law No. 7,797/1989	This law institutes the National Fund for the Environment (FNMA), in order to develop projects aimed at the rational and sustainable use of natural resources, including the maintenance, improvement or restoration of environmental quality in order to enhance the quality of life of the population.
Federal Law No. 9,985/2000	This law establishes the National System for Conservation Units (SNUC), defined as "territorial spaces and their environmental resources, including waters, with relevant natural attributes, legally instituted by the Government, with objectives of conservation and defined boundaries, under a special administrative regime, to which are applied adequate guarantees of protection". The Conservation Units can be classified in two groups: Full Protection and Sustainable Use. Each group can be sub-classified into diverse categories according to different specific objectives. The main objective of the Full Protection Areas is the preservation of nature, only allowing the indirect use of its resources. The basic objective of Sustainable Use Conservation Units is to combine both nature conservation and sustainable use of natural resources.
Federal Law No. 11,284/2006	This law addresses public forest management for sustainable production. It creates the Brazilian Forest Service (SFB) in the structure of the Brazilian Ministry of the Environment, establishes the National Forest Development Fund (FNDF) and makes other provisions.
Federal Decree No. 5,975/2006	This decree provides observations for the exploration, suppression and clear-cutting of forests and succeeding formations, and addresses the Sustainable Forest Management Plan, Forest Replanting and License to transport forest by-products.
Federal Decree No. 6,514/2008	This decree contains the regulations for the Environmental Crimes Act, and specifically administrative penalties.
Federal Decree No. 6,527/2008	This decree establishes the Amazon Fund by National Bank for Economic and Social Economic Development (BNDES).
Federal Decree No. 6,874/2009	This decree institutes Federal Program for Community and Family Forest Management (PMCF), established under the Ministry of Environment and Ministry of Agrarian Development, whose goal is to organise management actions and fostering sustainable management in forests that are subject to use by farmers, settlers reform land and the traditional peoples and communities.
Federal Complementary Law No. 140/2011	This complementary law co-ordinates the constitutional jurisdiction for protecting the environment and natural resources.
Federal Law No. 12,651/2012 Brazilian Forestry Code	This law establishes general rules on the protection of vegetation, Permanent Preservation Areas and Legal Reserve areas, forestry exploitation, supply of forestry raw materials, control of the origin of forest products and the control and prevention of forest fires and provides economic and financial instruments to achieve its goals. A Legal Reserve is an area where landowners or legal holders must conserve the native vegetation, where only the sustainable use of its resources is allowed. Permanent Preservation Areas are protected lands which can be covered or not by native vegetation, having the environmental role of preserving water resources, landscape, geological stability, biodiversity, genetic flow of fauna and flora, protecting the soil and ensuring the well-being of human populations.

Legislation	Comments
Federal Decree No. 8,375/2014	This decree defines the Agricultural Policy for Planted Forests and establishes the principles and objectives of the Planted Forest Policy for the production, processing and marketing of products, by-products, services and inputs for planted forests. Planted forests are considered to be forests composed predominantly of trees that result from sowing or planting, grown with economic focus and commercial purposes.
Federal Decree No. 8,972/2017	This decree institutes the National Policy for the Recovery of Native Vegetation.

2.2.4 Colombia

The entire forestry sector comes under the jurisdiction of the Ministry of the Environment. The Direction of Forests, Biodiversity and Ecosystem Services promotes the participation of communities in forest governance based on management, sustainable forest management, formulates and implements actions to prevent and control deforestation and degradation and implements the national plan restoration, recovery and rehabilitation of ecosystems, generates the technical and conceptual guidelines for the administration and management of national forest reserves (Law 2 of 1959 and national protectors) and strategic ecosystems as well as the formulation and monitoring of conservation policies , management and sustainable use of genetic resources.

In addition to advancing the evaluation of requests for subtraction of areas in the areas of national forest reserves, cites permits and contracts for access to genetic resources, as well as administrative actions in environmental sanctioning matters.

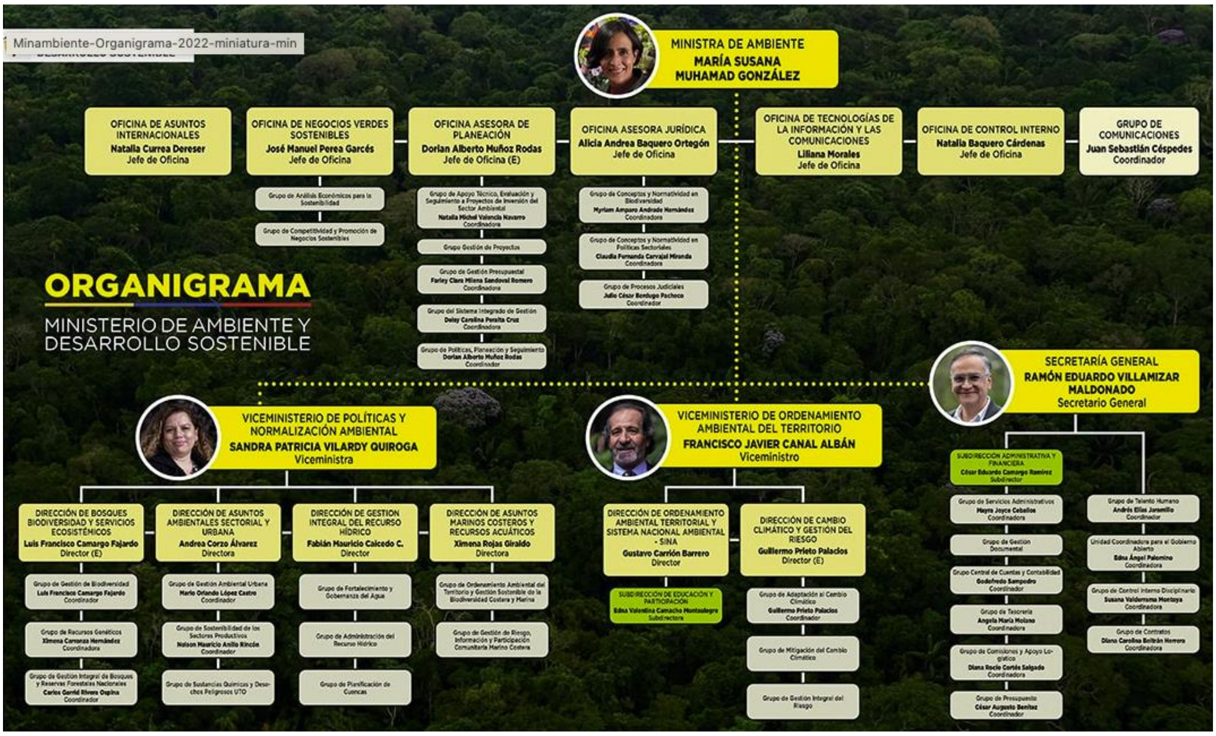

Figure 8: Organigram of the Colombian Ministry of Environment and Sustainable Development

National classification and definitions

The classification of forest areas is formalised in several documents throughout the years (Table 15).

Table 15: National classification of forest

Class	Definition
Forest plantation	Forest originated by reforestation (Decree Law 2811 of 1974).
Industrial forest plantation	The one established in a producing forest area with the exclusive purpose of allocating it to direct or indirect production (Decree Law 2811 of 1974).
Protective Forest Plantations	These are those that are established in protective forest areas to protect or recover some renewable natural resource and in which the use of secondary products can be made. such as fruits, latex, resins and seeds among others, ensuring the persistence of the resource. (Decree 1791 of 1996 Chapter XI, Art. 69). In accordance with Decree Law 2811 of 1974, this type of plantation is planted exclusively for protect or recover some renewable natural resource and of which indirect use can be made
Forest cultivation for commercial purposes	It is the cultivation of tree specimens of any size originated with the direct intervention of man for commercial purposes and that is able to produce wood and by-products. Forest plantations for commercial purposes are assimilated to industrial or commercial productive forest plantations referred to in Decree 1791 of 1996. (Decree 1498 of 2008)

As of 2012, with the formulation of the National Plan for the recovery, rehabilitation and restoration of disturbed areas, three additional definitions are involved in the concept of protective forest plantation

- Ecological Restoration (RE) Initiate or accelerate restoration processes of a degraded, damaged or destroyed area in relation to its function, structure and composition.
- Rehabilitation (REH) Repair productivity and/or ecosystem services in relation to functional or structural attributes.
- Recovery or reclamation (REC) Return the utility of the ecosystem for the provision of environmental services different from those of the original ecosystem

Policy

In Colombia, the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) is the official entity in charge of providing the knowledge, data and environmental information required by the Ministry of the Environment and other entities of the National Environmental System (SINA) for the evaluation, monitoring, follow-up and modeling of natural phenomena and human activities that affect ecosystems. One of the institute's main lines of research is knowledge of the country's forest resources, which is why, since 2007, the Forest Monitoring and Follow-up Program (PMSB) was formulated as a strategy for the consolidation of information on the knowledge and management of forests, support to support the definition of policies, plans, programs, projects in the matter and the promotion of responsibility, both of producers as well as users, in the generation of data and information on forest resources. The PMSB; seeks the integration of the actors involved in the management of information in the forestry sector (generating sources and users of the information), as well as the activities that generate effects on forest ecosystems and areas suitable for forestry, and identifies IDEAM as the entity that leads and coordinates its implementation.

In this context, and as a tool to strengthen national capacities in forest monitoring, in 2009, the implementation of a forest cover monitoring system began, which to date has been implemented. consolidated as the Forest and Carbon Monitoring System (SMByC) of IDEAM. The SMByC is established as the set of tools, procedures and professionals specialised in generating information that allows knowing where, when and why changes are happening on the surface and in the contents of carbon of the country's forests. The system performs the following activities:

- Identification and periodic reporting of official information on the area of natural forest.
- Generation of methodologies for the annual quantification of deforestation at the national level.
- Quarterly generation of Early Alerts for Deforestation (AT-D).
- Characterization, modeling and simulation of causes and agents of deforestation and degradation.
- Monitoring of carbon stored in forests (carbon stocks and GHG emissions).

International cooperation

Compliance with the 2030 Agenda and the Sustainable Development Goals (SDGs) requires the effort of all the actors in society around a new approach to development that seeks to reconcile its social, economic and environmental dimensions. In this context, the role of universities and research centers is central to achieving the SDGs as transforming agents and generators of knowledge.

Taking the above into account, the Center for the Sustainable Development Goals for Latin America and the Caribbean (CODS) seeks to become a meeting point that facilitates alliances between universities and academic institutions around the SDGs in the region. The CODS is the product of the initiative of the United Nations Sustainable Development Solutions Network (SDSN), led by Professor Jeffrey Sachs, and the Universidad de los Andes, located in Bogotá, Colombia.

In order to fulfill the purpose of contributing to the progress in the implementation of the SDGs in the region, from the academic field and through the collaborative work of institutions of excellence in the region, an alliance has been consolidated between the following Latin American universities: the State University of Campinas (Brazil), the International Center for Tropical Agriculture (Colombia), the Pontificia Universidad Javeriana (Colombia), the Universidad del Norte (Colombia), the Tropical Agricultural Research and Higher Education Center (Costa Rica), the Pontificia Universidad Católica de Chile (Chile), the Universidad del Pacífico (Peru), the Technological and Higher Education Institute of Monterrey (Mexico) and the National Autonomous University of Mexico (Mexico).

This group of institutions expressed, by signing a Letter of Intent, their commitment to contribute to the achievement of the SDGs and in particular to join efforts to their regional agenda through the CODS. In addition, with this agreement, general guidelines for joint work were drawn up in four priority areas: Research, Training, Advocacy and Sustainable Environments.

2.2.5 Ethiopia

Ethiopia’s forest coverage has been declining for decades at an alarming rate. Between 2000 to 2013, the net loss of forest cover was 72,000 hectares a year. In 2011, Ethiopia endorsed a Climate Resilient Green Economy (CRGE) strategy with the objective of building a green and resilient economy [URL40]. In direct relation to the SDG target 15, Ethiopia has been started the Green Legacy Initiative (GLI), launched in June 2019. A target of planting 20 billion seedlings within a period of four years was set. By the fourth year, Ethiopia has succeeded in planting 25 billion seedlings by mobilizing more than 20 million citizens throughout the nation. About 120,000 nurseries were established which created more than 767,000 jobs, mostly for women and youth. The Green Legacy Initiative is a demonstration of Ethiopia’s long-term commitment to a multifaceted response to the impacts of climate change and environmental degradation that encompasses agroforestry, forest sector development, greening and renewal of urban areas, and integrated water and soil resources management. This has an immense contribution to Ethiopia’s efforts to meet its international commitments such as the Paris Climate Change

Agreement, the 2030 Agenda for Sustainable Development, and Agenda 2063: The Africa We Want [URL40].

The Federal Government of Ethiopia, councils of Ministers have reorganized the Ethiopian Forestry Development (EFD) by merging the Ethiopian Environment and Forest Research Institute (EEFRI) and the Forestry sector from Environment, Forest and climate change Commission (EFCCC) in 2022 by regulation No. 505/2022. The Ethiopian Forestry Development clusters all forestry related topics in the country and has the power and duties to review and approval evidence-based policies, strategies, and legal instruments to facilitate the conservation, development, and sustainable use of forests. It includes all activities under the REDD+ scheme, SDG target 15 monitoring and reporting and the forestry development strategy. In general, SDGs are reported by several Institutions/Ministries in the country to the Ministry of Environment, Forest and Climate Change (MEFCC) – Ethiopia.

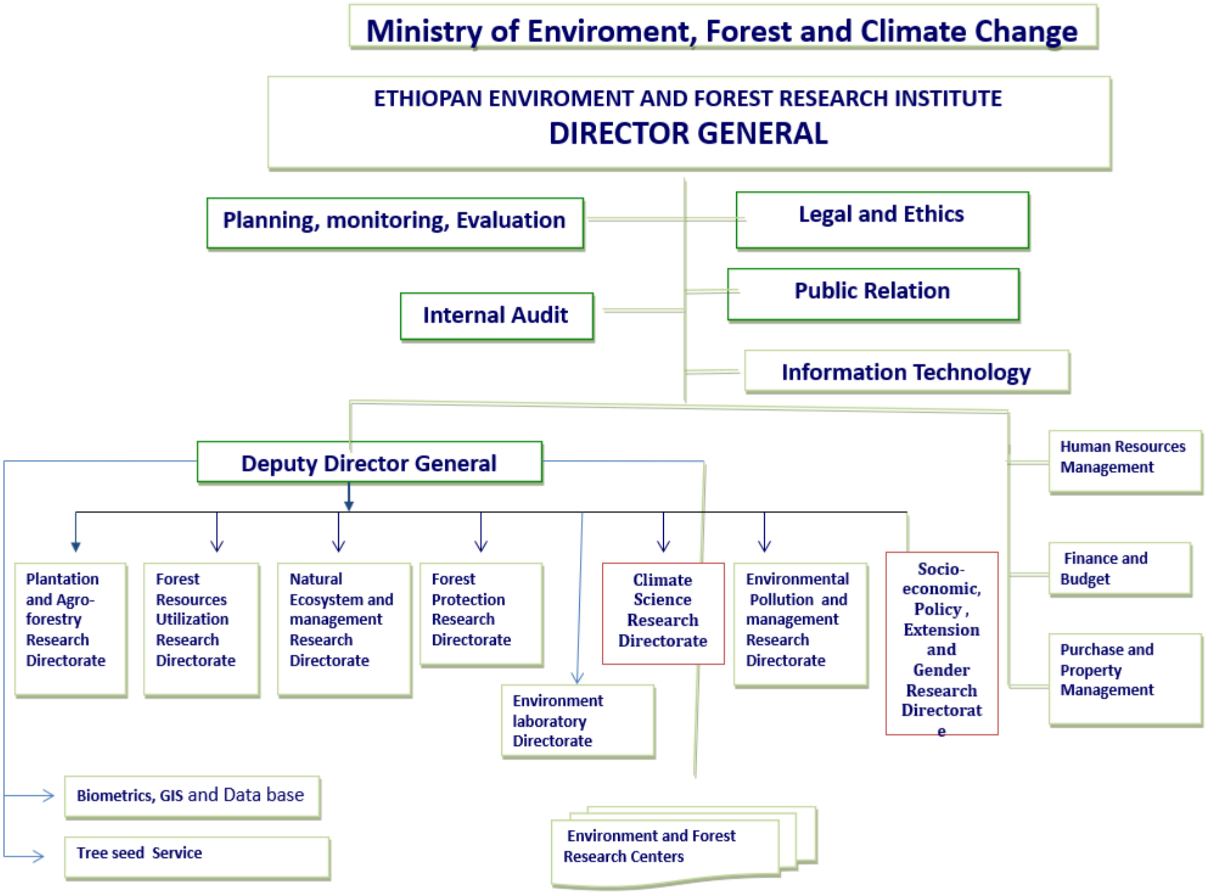

Figure 9: Organisational chart of the MEFCC [URL41]

Since more than two decades, many projects have been implemented in the forestry sector in Ethiopia from a wide range of implementation partner. The following table provides some examples of projects in Ethiopia that have the aim of improving the protection, management and resilience of Ethiopian forests.

Table 16: List of project examples in the forestry sector in Ethiopia

Project	Link
Forests4Future: Protecting forest landscapes through reforestation Funded by: German Federal Ministry for Economic Cooperation and Development (BMZ) Executing agency: Environment, Forest and Climate Change Commission in Ethiopia	[URL42]
Oromia Forested Landscape Program (OFLP) Supported by: World Bank's BioCarbon Fund Initiative for Sustainable Forest Landscapes (ISFL)	[URL43]
Promoting forest conservation through better marketing of wild coffee Funded by: Partnerships for Forests (P4F) Executing agency: Ethiopian Coffee and Tea Authority (ECTA)	[URL44]
Protecting nature, preserving biodiversity Funded by: German Federal Ministry for Economic Cooperation and Development (BMZ)	[URL45]
Conservation and sustainable use of natural resources in Ethiopia Funded by: German Federal Ministry for Economic Cooperation and Development (BMZ) Executing agency: Ethiopian Wildlife Conservation Agency & Amhara Forest Enterprise	[RD35]
REDD+ (Reducing Emissions from Deforestation and Forest Degradation) MRV (Measurement, Reporting, and Verification) system Commission Agency: PPP between GIZ, BlackBridge and Remote Sensing Solutions (RSS) Partner agency: National REDD+ Secretariat	[URL46]

3 Target User Group Characterisation

3.1 Vietnam

3.1.1 Addressed User Group

The Early Adopter user group includes the Forest Inventory and Planning Institute (FIPI). FIPI is the focal point for SDG reporting in Vietnam. The organisation conducts annual forest inventory assessment in hole country. The report is divided in two main thematic areas - reports on forest state and reporting on environmental state.

The Institute has been conducting work on state management and forest resources. Specifically, conducting baseline surveys on forestry including forest resources, land, flora, and fauna for the purpose of setting up many investment projects to build national parks, nature reserves, conservation of plant and animal genetic resources and plans for planning material zones for paper mills and other forestry industry. At the same time, the Institute carries out scientific research projects in the field of forestry, international cooperation activities and service activities for Agriculture and Rural development.

FIPI has some expertise in applying remote sensing information, GIS technology combined with field investigation to monitor and evaluate resources at cyclical or annual levels. It also develops economic and technical planning, investment projects for all levels on forestry and rural mountainous development. In addition, the institute is conducting research, surveys, produces topographic and thematic maps and curates the information on forestry resources and industry. FIPI is also involved in training local and foreign staff on forest survey and planning, organising seminars, short training sessions and guiding survey visits for domestic and foreign forestry scientists and researchers.

3.1.2 Current SDG Practices

Existing forest inventory programs in Vietnam

FIPI conducts a General Forest Inventory & Statistics Program (GFI&S) periodically (1989-1992; 1997-1999; 2011-2016) and generates forest cover maps for forest owners (previous cycles: for state forest owners only; current cycle: for all forest owners). The current cycle has two main steps, first forest cover maps are generated at the commune level based on SPOT-5 or equivalent imagery. Then forest statistics are extracted by overlaying forest cover maps with forest owner map. The data are sent to each owner for checking and updating. The method uses a random sampling system for estimating mean volume and thus is accurate but very expensive.

National Forest Inventory, Monitoring & Assessment Program (NFIMAP) is implemented since 1990 in 5-year cycles by FIPI. So far, 5 cycles have been completed (I: 1991- 1995; II: 1996-2000; III: 2001-2005; IV: 2006- 2010). The program has two main implementations. Forest cover maps are generated using satellite imagery. Forest inventory is conducted on an established sample plot system, The outputs from the program are forest cover maps at national, regional, provincial levels. Mean volume per ha for each forest type, as well as other forest characteristics such as forest structure, fauna, biodiversity, insect, pest, soil, socio-economy.

FIPI is tracking the sustainable development Indicators defined in Forest Management Strategy [RD15] (Chapter 2.2.1) FIPI is adopting the use of Satellite remote sensing in their methodologies. Forest areas changes are detected by using of different satellites images (Landsat, Spot (1-5), Sentinel-2).

FRA Reporting

Based on the requirements of each specific reporting table, the National Correspondent (staff member at FIPI Department of Science and International Cooperation) identifies all potentially useful data sources and evaluate the data sources according to content, completeness, quality, and compliance with FRA definitions. The compiled data is used to fill the FRA report.

Table 17: SDG Indicators with their data source based on the FRA 2020 country report for Vietnam [RD36]

SDGIndicators	FRA reporting	Data source
15.1.1 Forest area as a proportion of total land area	1a Extent of forest and other Woodland	NFCMP, NFI&S, NFI
15.2.1 Forest area net change rate	1d Annual forest expansion, deforestation and net change	Forest Protection Department (Vietnam Forest administration), NFCHMP
15.2.1 Above-ground biomass stock	2c Biomass stock	Forest Protection Department (Vietnam Forest administration), NFCHMP, NFI&S
15.2.1 Proportion of forest area located in legally established protected areas	3b Forest area within protected areas and forest area with long-term management plans	Forest Protection Department (Vietnam Forest administration), NFCHMP
15.2.1 Proportion of forest area under long-term forest management plans		Forest Protection Department (Vietnam Forest administration), NFCHMP
15.2.1 Forest area under independently verified forest management certification schemes	Data collected by FAO itself	

Forest inventory plots

FIPI has established a sampling plot grid across the country to collect and analyze in-situ forest parameters such as forest qualities, biomass, carbon stock. The sample plot system spans the forestry areas and has a regular 8 x 8 km grid.

For the 1991-95 forest inventory, a system of primary units systematically distributed over a grid of 8 km x 8 km in forest land was established. This grid was modified in 1996-2000 to 5.6 km x 5.6 (along diagonal) by inserting one more primary unit in the center of the four old primary units. These primary units are permanently located on the ground. A total of 1,800 sample were inventoried during Cycle I, from 1991 to 1995. During 1996-2005 (Cycles II and III) all the old 1,800 plots of Cycle I were repeated and about 1,500 additional plots were (were inventoried. The total number of plots in Cycle III was 4,200 in which 3,300 old plots and 900 additional plots in increasing forest area.

3.1.3 Gap Analysis and Challenges

Based on our literature review and the discussion with the representatives in FIPI we can summarise the following challenges in the forestry sector of Vietnam.

- Difficult terrain, lack of funds and limited personnel to carry out the necessary measurements hampers progress in monitoring
- Old land maps and unclear boundaries between land types have lead to a situation where many forest land certificates do not match the area being managed because the authorities use different data or measurement methods for different areas.

- Deforestation and forest degradation take place mostly in the North Central, Northeast, Central Highlands, and Northwest of Vietnam.
- Digital technologies are poor and outdated
- Technical and managerial human resources are lacking and weak
- Climatic change increases the frequency of extreme weather events especially fire and erosion
- AGB estimations based on tree height are prone to error due to the complex canopy structure in tropical forests. The forests in Vietnam can have up to 5 canopy stories.
- Climate change is increasingly felt in Vietnam. An observable increase in the frequency of extreme weather events. Drastic increase in catastrophic events, particularly fire, cold spells, and prolonged drought.
- In north central region sees between 2000 and 3000 mm of annual rainfall. This occurs predominantly in the summer period leading to flooding, erosion, and increased landslide risk.
- In addition, the North Central region is where the largest Forest on limestone bedrock is located. Limestone has porous structure.
- The coastal regions of North Central region are primarily used for agriculture and plantations. There is a very small amount of mangrove forest along the deltas of the rivers draining into the South China Sea.

3.2 Germany (Federal State Hessen)

3.2.1 Addressed User Group

HessenForst

HessenForst is the forestry authority for the German federal state of Hessen, organised into 39 forestry offices and 390 forest districts and one of the major forestry operations in Central Europe. Hessen has a total area of 21,115 km², of which about 42 % is covered with forest. Almost 80 % of this forest is managed by Hessenforst, in particular the 3,420 km² of state forest, but also a large part of the Hessian corporate and private forest [URL47, URL 48]. HessenForst carries out the annual forest environmental monitoring and the NFI for Hessen.

Thünen Institute

The Thünen Institute is a scientific research institute with 15 specialised institutes headquartered in Braunschweig, Germany. One of its research areas is forest, comprising the institutes for wood research, forest management, forest genetics and forest ecosystems, which coordinates the annual forest environmental monitoring and the NFI for Germany [URL49]. For the FRA, the Thünen Institute assumes the role of national specialists and collaborators for Germany.

Federal Ministry of Food and Agriculture

The Federal Ministry of Food and Agriculture (ger: "Bundesministerium für Ernährung und Landwirt-schaft" (BMEL)) is the highest federal authority of Germany with its headquarters in Bonn. It is the designated national correspondent for the FRA and reports the SDG indicators based on the data sources indicated in Table 18.

3.2.2 Current Sustainable Practices

HessenForst is managing their forest according to the principles of sustainability, paying attention to a balanced relationship between ecological, economic and social interests. The basis for the protection of the forest is the nature conservation guideline, which has been in force since 2011 and was recently updated in 2022 [URL50]. The sustainable forest management of HessenForst is certified with the PEFC and FSC certificates [URL51]. Additionally there are numerous protected areas in Hessen, such as the national park Kellerwald Edersee and the Natura2000 network. This network comprises 583 Flora-Fauna-Habitat-areas and 60 bird sanctuaries in Hessen. Of these, 75 % of the Flora-Fauna-Habitat-areas and 60 % of the bird sanctuaries are located in forests [URL52]. In addition, there are 2300 natural forest development areas on 32 hectares in Hessen, where the forest can develop without human influence. Furthermore, habitat trees of animal species are protected, and special attention is paid during the breeding and rearing season [URL53].

To better understand the changes in Hessen´s forest ecosystems, forest condition surveys have been systematically carried out since 1984. Today, this forest environmental monitoring includes overview surveys (level 1), targeted investigations of selected forest ecosystems with higher measurement intensity (level 2) and research into the effects of forest management measures on experimental plots (level 3). The overview surveys are carried out in a systematic, representative in-situ sampling grid for the assessment of forest and soil condition every year. The grid size for this level 1 monitoring is 8 km x 8 km, which currently corresponds to a total of 128 survey points for Hessen. In the forest condition survey, the visible health or damage condition of the individual sample trees is assessed visually. The core parameter here is crown defoliation, but fruiting, yellowing of leaves or needles, insect and fungal infestation as well as trunk and crown injuries are also recorded. In doing so, the methodology of forest environmental monitoring follows the Europe-wide harmonised principles of the ICP Forests of 2016. As a central component of forest environmental monitoring, the results are evaluated and summarised in the annual Forest Condition Report, which provides information on the vitality of forest trees and the stress factors for forest ecosystems [RD37].

In addition to the annual forest environmental monitoring for Hessen, the NFI (Bundeswaldinventur) is carried out every 10 years for the whole of Germany, which serves as the information basis for the FRA. The implementation in Hessen of this nationwide project is also carried out by HessenForst. The data of more than 150 features is collected in a systematic sampling grid with a grid size of 4 x 4 km, with some federal states regionally densifying the grid by double (2.83 km) or quadruple (2 km). For each measuring point in the forest, for example, the tree species, diameter and height are recorded for selected sample trees, as well as data on regeneration, stocking structure and dead wood. In the current NFI 2022, it is planned to use remote sensing data for regional analysis to complement the in-situ measurements and increase spatial resolution [URL54]. These forest monitoring practices underline HessenForst's status as a competence user with comprehensive sustainability measures.

In the FRA 2020 for Germany the SDG indicators were reported like shown in Table 18.

Table 18: SDG Indicators with their data source based on the FRA 2020 country report for Germany [RD38]

SDG Indicators	FRA reporting	Data source
15.1.1 Forest area as a proportion of total land area	1a Extent of forest and other Woodland	FRA 2015: NFI 2012
15.2.1 Forest area net change rate	1d Annual forest expansion, deforestation and net change	FRA 2015
15.2.1 Above-ground biomass stock	2c Biomass stock	NFI 1987, Datenspeicher Waldfonds (DSWF), NFI 2002, Inventurstudie 2008 (IS 2008), NFI 2012

SDG Indicators	FRA reporting	Data source
15.2.1 Proportion of forest area located in legally established protected areas	3b Forest area within protected areas and forest area with long-term management plans	FRA 2015: combination of Natura2000 and Corine Land Cover class 3
15.2.1 Proportion of forest area under long-term forest management plans		NFI and estimation
15.2.1 Forest area under independently verified forest management certification schemes	Data collected by FAO itself	FSC, PEFC or other schemes

3.2.3 Gap Analysis and Challenges

Climate change with drought and prolonged heat waves has severely affected the forest in recent years. Since 2019, the Hessian forests have been in a persistently poor state of vitality and a strong destabilisation of forests conditions has occurred. In the vegetation year 2021/2022, the average precipitation in Hessen was just under 80 % of the long-term average of 790 mm, and with a mean temperature of 10.3 °C, the year 2021/2022 was one of the warmest since measurements began. These conditions have lowered forest resilience particluarly towards natural hazards such as storms and parasites. The forest condition report of 2022 reports 9% of total forest area have suffered severe damage, which is three times higher than the annual average since 1984. Likewise, the mortality rate (0.9 % in 2022) and the failure rate due to storm damage, drought, and bark beetle infestation (2.7 % in 2022) have also increased in the last four years. As a result, structural disturbances have occurred, many of which have resulted in open spaces, patches and gaps in the forest stands [RD39].

To address these challenges, it is essential to have a comprehensive understanding of forest dynamics. For this purpose, HessenForst conducts regular forest monitoring surveys using a representative in-situ sampling network, as described in detail in chapter 3.2.2. To complement these data collections, EO data can provide additional helpful, exhaustive information with an even higher temporal resolution, higher spatial coverage while minimizing ground effort. For example, EO data-based vitality indicators could have been used to continuously monitor the forest condition in recent years to better understand and predict the damage caused. Remote sensing-based methods can also help to monitor the newly created open spaces and understand local biodiversity dynamics and differentiate stages of tree growth for a more effective reforestation.

Next to a more efficient forest management, EO can improve SDG reporting. For example, in the case of Germany, the SDG indicator 15.1.1, forest area as a proportion of total land area, which has been almost constant for a decade is misleading (Figure 10).

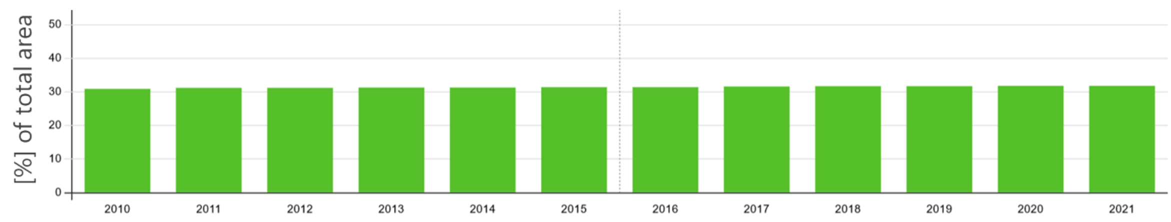

Figure 10: SDG Indicator 15.1.1: Forest area as a proportion of total land area (timeseries for Germany) [URL55]

The reason for this is the German forest definition from the German Forest Act, which defines forest areas independently of their forest condition. Thus, bare or thinned ground areas are also considered forests. With the help of more insightful remote sensing-based indicators, the actual forest dynamics can be tracked with a closer reference to reality. In general, the forest management in Hessen can benefit from the numerous advantages of EO to support a more insightful monitoring of the sustainable development of the forest ecosystems.

3.3 Brazil

No previous contact with Brazilian entities/institutions was established before the project kick-off meeting in early November 2022. Nevertheless, with nearly half a billion hectares of natural and planted forests (second most forested country in the world, representing around 60% of Brazilian territory) and around 330 million hectares in the Amazon forest itself, it goes without saying that Brazil can be considered as a key country, and has an outspoken and strong need for strategic information on its forestry resources in order to elaborate effective national policies and evaluate their outcomes. However, despite its strong forestry vocation, Brazil still lacks a functional mechanism to generate needed information. The latest and only nationwide forest inventory in Brazil was conducted in the early 1980's and the information requirements have since then continuously increased and evolved.

3.3.1 Addressed User Group

Forest policies and management in Brazil involves different institutions and is shared among the three levels of government: federal, state and municipal. At the federal government level, forest management lies under the direct responsibility of several institutions (Table 19).

Table 19: Forest management institutions at the federal level in Brazil

Federal institution	Link
The **Ministry of Agriculture, Livestock and Food Supply (MAPA)** is responsible for coordinating, planning, implementing and evaluating the agricultural policy for forest plantations.	[URL56]
The **Ministry of the Environment (MMA)** is responsible for granting the rights for the sustainable production in federal public forests under concession contracts.	[URL57]
The **Brazilian Forest Service (SFB)** is the managing agency of federal public forests for sustainable production of goods and services. It also holds the responsibility of generating information, training and fostering the forest sector.	[URL58]
The **Brazilian Institute of Environment and Renewable Natural Resources (IBAMA)** is the agency responsible for environmental licensing, monitoring, controlling and inspection.	[URL59]
The **Chico Mendes Institute for Biodiversity Conservation (ICMBio)** is the institution responsible for proposing, implementing, managing, monitoring and protecting the federal Conservation Units.	[URL60]
The **National Environmental Council (CONAMA)** is the consulting body that deliberates on the National Environmental System (SISNAMA). It is a collegiate body which represents federal, state and municipal environmental agencies, the private sector and civil society.	[URL61]
The **National Forest Commission (CONAFLOR)** provides guidelines on the implementation of the National Forests procedures and allows the joint participation of various interest groups in developing public policies for the forest sector. CONAFLOR has the main role in the process of putting in practice the National Program of Forests and by now it is dealing with the review of the National Forest Code, the National Report of Genetic Forest Resources, the National Study of Brazilian Forest Sector and the inclusion of the subject "Forests" in the multiannual Brazilian plans. It is composed of 39 representatives distributed equally between the government (20) and civil society (19), including some federal government agencies and entities, state	[URL62]

Federal institution	Link
environmental agencies, civil society groups, forestry sectors, NGOs and educational and research institutions.	
The **Commission on Public Forest Management (CGFLOP)** is an advisory body of the Brazilian Forest Service which aims to advise, evaluate and propose guidelines for the management of public forests in Brazil, especially regarding the Annual Plan on Forest Concession (PAOF), which deals with identification, selection and description of public federal forests or potential areas for concession.	[URL63]

Figure 11 gives an overview of the institutional organisation regarding forest management in Brazil according to the different government levels.

Figure 11: Forest management institutional organisation in Brazil

The FAO global forest resources assessment 2020 Brazilian report [RD40] was analyzed in order to identify the people/entities/institutions mainly involved in this process, and hence to target potential Early Adopters. Therefore, the following organisms were considered:

<u>Brazilian Forest Service</u>

The Brazilian Forest Service (BFS) (Portuguese: Serviço Florestal Brasileiro, SFB) [URL63], created in 2006, is the institution responsible for coordinating the National Forest Information System (NFIS) [URL64]. The NFIS aims at producing, organising, storing and processing data, information and knowledge on forest resources and the forestry sector to support conservation and the sustainable use of forests. Since the BFS creation, the availability of forest information is continuously increasing, as well as the capability of the country to report at national and international levels.

Federal University of Amazonas

The Federal University of Amazonas (Portuguese: Universidade Federal do Amazonas, UFAM) is a public university located in Manaus, Amazonas, Brazil. It is the oldest university in Brazil and one of the largest universities in the northern region of Brazil, offering a wide array of degrees, with 645 research groups and 65 graduate courses. For almost thirty years investing in the training of forest engineers, the Federal University of Amazonas, through the Forestry Department, has continuously promoted the consolidation of the Forestry Engineering course, addressing four major areas of forestry sciences: silviculture, nature conservation, technology and management.

To date, the link with potential Brazilian Early Adopters is very thin and the amount of information/requirements provided on the Brazilian Forestry policy or current SFM practices is very limited. Nevertheless, considering its importance and the numerous stakes linked to forestry and SFM in Brazil, it seems important and still relevant to try to keep the contact with Brazilian users.

To maximize our chances of success with Brazil, another option has also been considered, exploiting the link already established with the CODS in Bogota (Colombia). Given its international competence and to rely on their network, the possibility to work on a joint project between the two countries, Brazil and Colombia will be analyzed and assessed together with the CODS. One possibility could be for instance to evaluate the deforestation and forest degradation over areas of the Amazon rainforest and to assess the impact on indigenous communities by working on socio-economic indicators. Should this option be considered interesting enough by the CODS, it could be really valuable to the project as it would broaden its scope both in terms of content and territory.

3.3.2 Current Sustainable Practices

Brazil has participated regularly in the global forest resources assessments coordinated by FAO and since 2005 it is working for improving the quality of forest information at country level.

That same year (2005) the Brazilian Ministry of Environment has initiated the process to establish a nation-wide forest monitoring system based on national forest inventories including systematic field data collection and remote sensing surveys. This initiative was set up thanks to a multi-institutional Technical Committee made up of Brazilian and international specialists from governmental institutions, research stations, universities and the civil society with the aim of developing an inventory based on systematic sampling for field data collection and remotely sensed landscape mapping.

The Brazilian Forest Service is also responsible for organising and implementing this nation-wide inventory, namely the National Forest Inventory (NFI) [URL65]. The BFS has since then run a testing programme to organise pilot field tests of the methodology in different parts of the country in order to validate and improve its applicability in the country's great variety of ecosystems and biomes (Amazônia, Caatinga, Cerrado, Mata Atlântica, Pampa and Pantanal).

The NFI's methodology has a national standardization, with possible adaptations to the peculiarities of Brazilian biomes. The methodology consists of gathering biophysical, socio-environmental and landscape information in a systematic grid of sample points measuring 20 km x 20 km and covering the entire national territory at intervals of 5 years.

The use of Earth Observation is also established within Brazilian institutions for several years to support forestry policies in a range of different applications. Monitoring natural forest cover loss in Brazilian biomes is an example of such applications, and is realized with the support of various projects:

- The Monitoring Program of Brazilian Biomes by Satellite (PMDBBS), carried out by IBAMA for actions to control and combat illegal deforestation [URL66];
- The Forest Satellite Monitoring Project (PRODES), carried out by INPE in the Legal Amazon and Cerrado biomes, to measure annual deforestation rates [URL67];
- The Atlas of the Atlantic Forest Remnants, an agreement between the SOS Mata Atlântica Foundation and INPE for Monitoring the Atlantic Forest [URL68];
- The Environmental Monitoring Program of the Brazilian Biomes (PMABB), a partnership between the Ministry of the Environment, INPE, Embrapa and IBAMA to monitor the Brazilian biomes [URL69].

Monitoring the heat spots and forest fires is another example where satellite imagery can bring some support to the Brazilian authorities through INPE's Queimadas Program [URL70]. This program started operating in 1986 during a conjoint field experiment between INPE researchers and NASA. Is has evolved continually since 1987, when it started operating nationally, and it has improved especially after 1998, with the support of the national Proarco National Program, from IBAMA, created to control burnt areas and deforestation in the "arch of deforestation" in the Amazon, with resources from the Ministry of Environment.

In the FRA 2020 for Brazil the SDG indicators were reported like shown in Table 20.

Table 20: SDG Indicators with their data source based on the FRA 2020 country report for Brazil [RD40]

SDGIndicators	FRA reporting	Data source
15.1.1 Forest area as a proportion of total land area	1a Extent of forest and other Woodland	FRA 2020, Instituto Brasileiro de Geografia e Estatísticas (IBGE) - 2009
15.2.1 Forest area net change rate	1d Annual forest expansion, deforestation and net change	FRA 2020, INPE - 2017, IBAMA - 2009, 2011
15.2.1 Above-ground biomass stock	2c Biomass stock	FRA 2020, NFI - 2018
15.2.1 Proportion of forest area located in legally established protected areas	3b Forest area within protected areas and forest area with long-term management plans	FRA 2020, National Register of Conservation Units (CNUC), Indian National Fundation (FUNAI)
15.2.1 Proportion of forest area under long-term forest management plans		
15.2.1 Forest area under independently verified forest management certification schemes	Data collected by FAO itself	FSC, PEFC or other schemes

3.3.3 Gap Analysis and Challenges

Concrete discussion on the current state of SDG reporting including gap and challenges will be continued upon establishing a regular exchange with national representative.

3.4 Colombia (CODS)

During the preparation of the response to the call, we communicated with many potential contacts in Latin America and Africa. Taken by time, some entities could not answer us within the time limit, but we managed to maintain contact. However, some of our interlocutors have a very busy schedule which does not allow them to respond to our requests. In Africa, we rely on a colleague who is very involved in the field of earth observation on a continental scale.

We have chosen to include the CODS in the Early Adopters group and in this document, because it is both a national and international organisation, and which carries out its activities in the public sector, while striving to develop partnerships of all kinds. The CODS has also shown its availability and interest in the project and is the most responsive to date for participation in meetings and responses to questionnaires.

3.4.1 Addressed User Group

The Center for the Sustainable Development Goals for Latin America and the Caribbean (CODS) is part of the United Nations Sustainable Solutions Network (SDSN), led by Jeffrey Sachs of Columbia University. It is a place for meeting and thinking about SDGs in alliance with universities of excellence and research centers in Latin America and the Caribbean.

The process of establishing the Center has been guided by a committee made up of professors from the Faculty of Administration and the Faculty of Economics of the Universidad de los Andes, as well as members of the SDSN.

The main objective of the Center is to become a meeting and thinking place on the Sustainable Development Goals (SDGs) in alliance with universities of excellence, companies, governments and civil society organisations in Latin America and the Caribbean. The Center aims to become a platform for the dissemination of knowledge and contribute to the training of the next generation of leaders in sustainable development in the region and to monitor and evaluate policies and programs in the region, to contribute to the achievement of the SDGs.

In addition, it also seeks to contribute from the region's experience to global discussions of the SDGs, as well as design and lead a research agenda related to the most relevant SDGs for the region. To achieve these objectives, CODS has identified the following key aspects of its mission:

- Emphasis on the interconnection between the social, the economic and the environmental and on the understanding of the synergies, trade-offs and relationships between different SDGs.
- Permanent search for alliances, connecting existing efforts and enhancing the role of academia and knowledge for the fulfillment of the SDGs in the region.
- Creation of inter-university teams and new networks in the region with the capacity to produce high-quality interdisciplinary research on the countries of Latin America and the Caribbean (regional and sub-regional research)
- Generation of new ways of measuring progress in the implementation of the SDGs
- Incorporation of sustainability in the daily life of the partner universities are also differentiating factors of the Center.

3.4.2 Current Sustainable Practices

National definition of forested land: Land occupied mainly by trees, may contain bushes, palms, Guadua bamboo, herbs and vines. Land where the tree coverage has a density of at least 30% of canopy with a minimum height on site of 5 m once its identified, and a minimum area of one hectare. The definition of national forest excludes covered commercial forested land, palm crops and sown trees for agricultural production. These types of covered land are called non forested land.

Minimum size and minimum relative canopy cover for area to be defined as forest: Land where the tree coverage has a density of at least 30% of canopy with a minimum height on site of 5 m once its identified, and a minimum area of one hectare.

Different forest categories according to their origin:

- Bosque regenerado naturalmente (naturally regenerated forests)
- Bosque primario (primary forests)
- Bosque plantado (planted forests)
- Otra cobertura arbórea (other tree coverage)
- No forestal (non forest)

In the FRA 2020 for Colombia the SDG indicators were reported like shown in Table 21.

Table 21: SDG Indicators with their data source based on the FRA 2020 country report for Colombia [RD41]

SDG Indicators	FRA reporting	Data source
15.1.1 Forest area as a proportion of total land area	1a Extent of forest and other Woodland	FRA 2020, INVEMAR 2016
15.2.1 Forest area net change rate	1d Annual forest expansion, deforestation and net change	FRA 2020, IDEAM 2017, 2018
15.2.1 Above-ground biomass stock	2c Biomass stock	FRA 2020, IDEAM 2018
15.2.1 Proportion of forest area located in legally established protected areas	3b Forest area within protected areas and forest area with long-term management plans	RUNAP (single national register of protected areas single)
15.2.1 Proportion of forest area under long-term forest management plans		RUNAP, SINAP, IDEAM
15.2.1 Forest area under independently verified forest management certification schemes	Data collected by FAO itself	FSC, PEFC or other schemes

3.4.3 Gap Analysis and Challenges

The data comes from inventories carried out in certain years. They are collected by different services, depending on their field of intervention. There are therefore difficulties in the continuity and homogeneity of the data.

3.5 Ethiopia

3.5.1 Addressed User Group

Based on previous activities in Ethiopia, RSS established contact to the Ethiopian Forestry Development (EFD), which is the leading governmental entity that is responsible for all forestry related aspects in Ethiopia, including the SDG 15 monitoring and reporting. The EFD expressed their willingness to act as an Early Adopter in the project and also assigned a MRV expert that will contribute in the co-design. A representative of the EFD gave a presentation on the activities of the forestry sector in Ethiopia and especially highlighted the ambitious Green Legacy Initiative (GLI).

3.5.2 Current Sustainable Practices

The forest sector plays a significant role in the national economy since forest resources supply important wood and non-timber forest products [RD42]. During the last decades, there is an increasing pressure on forest resources due to agricultural expansion, cattle ranging and fuelwood collection, resulting in high levels of deforestation and forest degradation [RD42, RD43]. For the year 2010, the remaining forest resources of Ethiopia were estimated to store 172 million tonnes of carbon in their above ground biomass, with the same amount stored in other wooded lands [RD44]. With an estimated average annual deforestation rate between 1.0-1.5% ([RD45], this carbon stock will be lost by the end of this century if the deforestation rate continues unabated. Local consequences will be shortage of wood and non-timber products, depletion of biological resources and further degradation of vegetation resources as well as widespread land degradation [RD46].

However, the figures on existing forest resources and carbon stock in Ethiopia vary greatly and thus estimates on forest cover changes and related Green House Gas (GHG) emissions inherent a high level of uncertainty. Whereby the Woody Biomass Inventory and Strategic Planning Project (WBISPP) estimates the coverage of forest around 3.3 million ha, the Food and Agriculture Organisation of the United Nations (FAO) estimates the total forest cover to about 12.3 million ha [RD47, RD44]. Earth Observation (EO) can significantly contribute towards an improved data base on forest resources and to lower uncertainty levels of deforestation and GHG emission estimates [RD48].

In the FRA 2020 for Ethiopia the SDG indicators were reported like shown in Table 22.

Table 22: SDG Indicators with their data source based on the FRA 2020 country report for Ethiopia [RD49]

SFG Indicators	FRA reporting	Data source
15.1.1 Forest area as a proportion of total land area	1a Extent of forest and other Woodland	Land use / land cover map 2013, Ministry of Environment, Forestry and Climate Change (MEFCC) Ethiopia's Forest Reference Level Submission to the UNFCCC, March 2017
15.2.1 Forest area net change rate	1d Annual forest expansion, deforestation and net change	Ethiopia's Forest Reference Level Submission to the UNFCCC, March 2017
15.2.1 Above-ground biomass stock	2c Biomass stock	Ethiopia's NFI. Final Report, Ministry of Environment, Forest and Climate Change, 2018.
15.2.1 Proportion of forest area located in legally established protected areas	3b Forest area within protected areas and forest area with long-term management plans	No specification
15.2.1 Proportion of forest area under long-term forest management plans		
15.2.1 Forest area under independently verified forest management certification schemes	Data collected by FAO itself	No specification

3.5.3 Gap Analysis and Challenges

Ethiopia’s Climate-Resilient Green Economy (CRGE) strategy aims at developing a green economy by avoiding GHG emissions and unsustainable use of natural resources [RD50]. The CRGE strategy involves several sectors, such as agriculture, energy and forestry, whereby Reducing Emissions from Deforestation and forest Degradation plus (REDD+) is considered as a major opportunity for GHG emission reduction. Ethiopia is a partner country in the UN-REDD+ programme and the Forest Carbon Partnership Facility (FCPF) and the World Bank are supporting Ethiopia in its efforts towards establishing the key pillars of REDD+ Readiness. REDD+ Readiness requires the development of a national REDD+ strategy, the institutional, technical and human capacity, the implementation of a Measurement, Reporting & Verification (MRV) system and the development of baselines/reference scenarios (FDRE 2011a). The main challenge thereby is to demonstrate that a REDD+ strategy is established and that emissions of verified amounts of CO2 equivalents can be reduced by reducing deforestation and forest degradation. In order to prove this, Ethiopia must implement an MRV system, that properly assess the area covered by forest, quantifies its carbon stock and monitors forest cover changes. EO has become an integral part of REDD+ MRV systems. Therefore, innovative satellite systems, high performance hard- and software for data analysis and technical expertise are fundamental requirements.

Even though many projects and activities have been already taking place in Ethiopia, in which Earth Observation data was used to assess forest resources and status, these activities still seem to be fragmented. The main challenge will be the streamlining of Earth Observation-based approaches for Forest mapping that will also be accepted by governmental institutions and which might be used for the SDG reporting by official entities.

Especially for SDG 15 "Life on Land", satellite remote sensing could be beneficial for improving the indicator assessment. As shown in the SDG Index country overview [RD51], the SDG target 15 in Ethiopia remains challenging, which is partly caused by a lack of regularly updated and robust data.

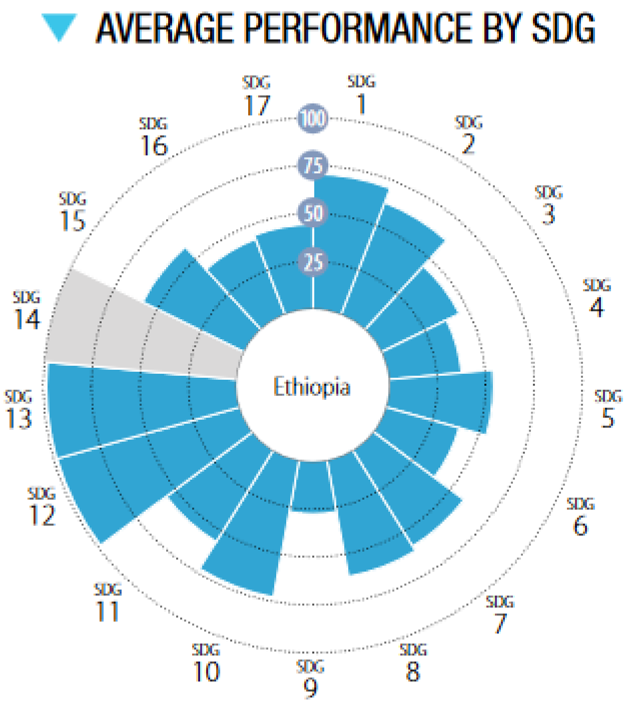

Figure 12: Performance indication by SDG for Ethiopia [RD51]

3.6 West Africa

3.6.1 Addressed User Group

As far as West Africa is concerned, when the project was submitted, we received two letters of support:

- Ministry of Water and Forests in Côte d'Ivoire
- Ministry of Forests in Cameroon

These two countries have since confirmed their interest in participating in the project, but their lack of availability does not allow them to invest as much as the consortium would like. Nevertheless, we maintain contact and the dissemination of information, in particular thanks to the support of our contacts in Cameroon, and who have a very good network throughout the African continent. During series of conferences had brought together many participants from all over Africa.

The two ministries correspond to our expectations in terms of level of interlocutor, and that is why we want to keep them in our project. At a minimum, we will continue to disseminate information on the project and in particular the development of products. We hope to be able to go further in our ambitions by meeting their expectations.

3.6.2 Current Sustainable Practices

Ivory Coast has decided to elaborate a forest monitoring and deforestation early warning system. Documents for the establishment of a National Forest Spatial Monitoring System currently being validated with biannual updating of the land use map/land cover map with reference year 2020 being validated. In addition, Ivory Coast launched several land and forest restoration initiatives led by different national players (difficulties encountered in reporting initiatives). Ivory Coast wishes to integrate indicators for the management and protection of water resources in forests.

Ivory Coast and Cameroon are member of the AFR100. AFR100 (African Forest Landscape Restoration Initiative) is an international partnership between African nations, financial interests both donor and business, technical organisations, and local interests which aims to restore more than 100 million hectares of land in Africa by 2030.

3.6.3 Gap Analysis And Challenges

The two countries have comparable profiles with high deforestation and cocoa cultivation. The two countries have defined ambitious policies but have not yet taken action to put in place effective methods for calculating the SDGs. The project can therefore provide them with effective means of monitoring the implementation of their policies.

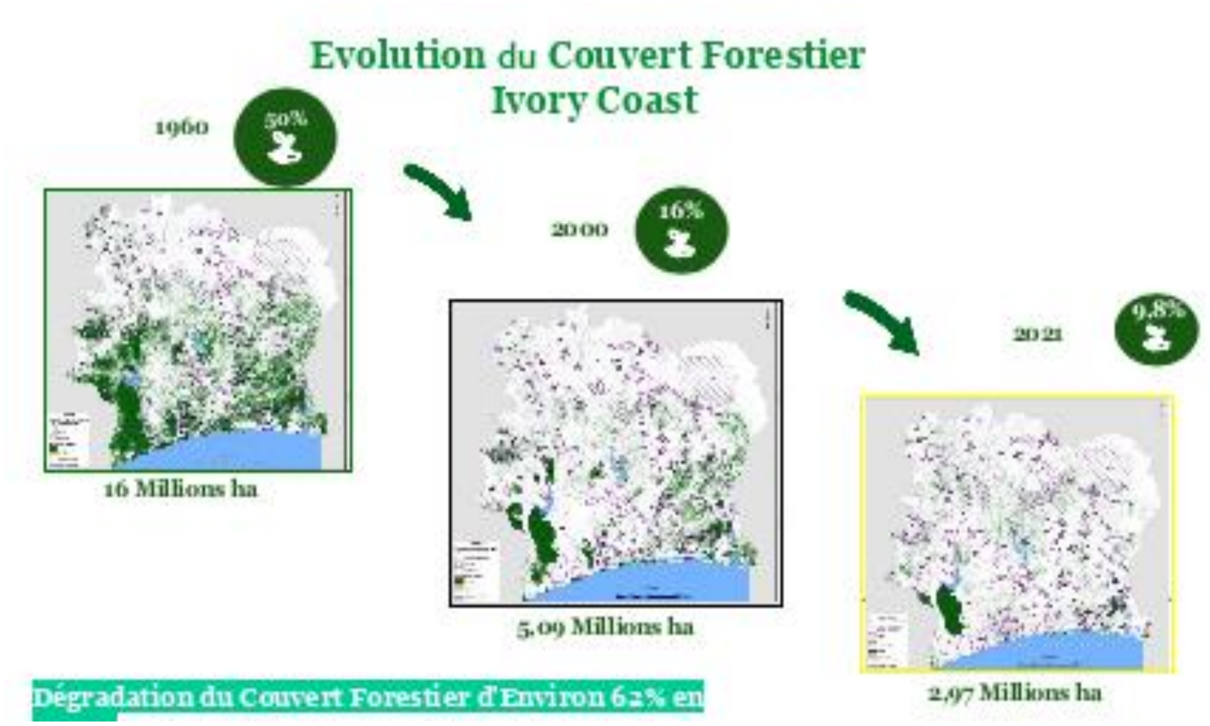

Figure 13: Historical development of forest cover in Ivory Coast

Figure 14: Principal causes of deforestation

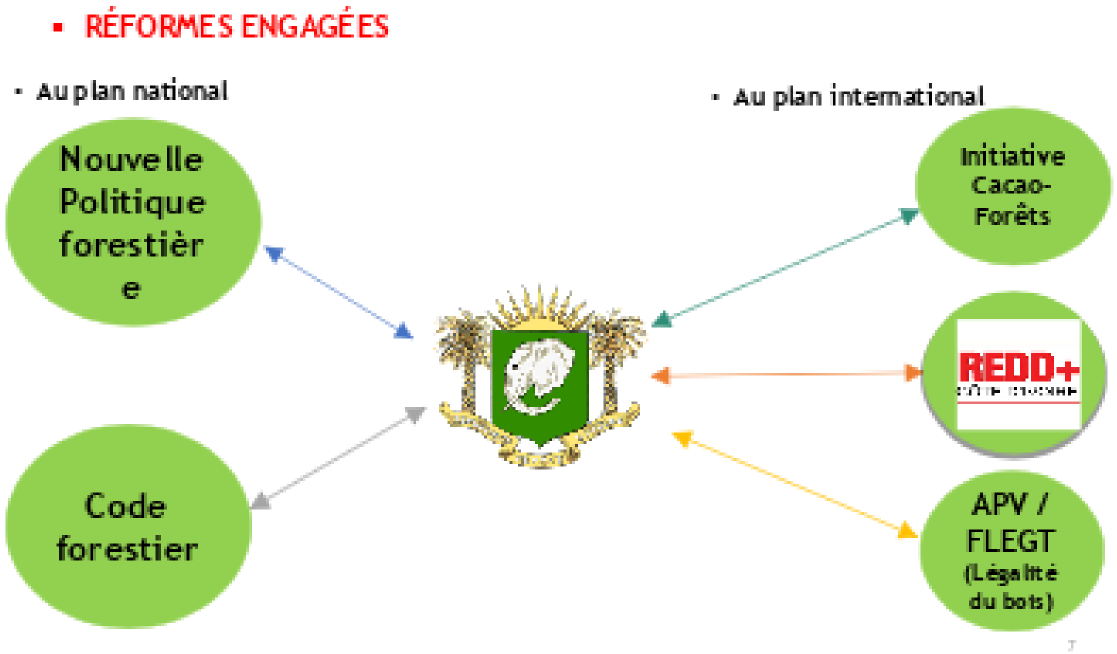

Figure 15: National and international initiatives in Ivory Coast

We are also looking, based on these two countries and Monique's work, to develop locally, in West Africa, a network of users of our project. The contacts made in Rabat by Monique during the GMES4AFRICA meeting should quickly give us potential correspondents in some African countries that would be interested.

4 State of the Art Earth Observation Methods

4.1 Earth Observation Best Practices

Over the past decade, the European Space Agency (ESA) has been examining the field of development cooperation and sustainable development goals as a long-term perspective for the use of environmental information from satellites. These activities began with the first demonstration projects as part of the eoworld and eoworld2 initiatives, via the "Earth Observation for Sustainable Development" (EO4SD) initiative, and since the end of 2021 with the Global Development Assistance Program (GDA). The strategy and main focus is on cooperation with international organisations in the development sector, in particular the World Bank, the Asian Development Bank and the International Fund for Agricultural Development (IFAD). The ESA has published various reports presenting the range of possible uses of EO in development cooperation [RD52, RD53, RD54, RD55], and also presenting the needed activities required to further disseminate the use of EO in development cooperation [RD56]. Numerous projects in the field of environment and climate in various sectors such as agriculture, forestry and in the urban environment use remote sensing information to answer various questions relevant to development policy. These in turn provide the basis and orientation for further action.

4.1.1 Best practice examples for SDG 15 – Life on Land

Measures to protect forests, to prevent deforestation and forest degradation, to introduce sustainable forest management and to improve and restore forest ecosystems have already been in the focus of development policy goals for many years. Examples are the framework for REDD+ (reducing emissions from deforestation and forest degradation), improving legislation, governance and trade in forest products (FLEGT), managing protected areas to strengthen, to establish new sustainable forestry value chains and to advance the restoration of forests. In almost all activities, geoinformation and especially earth observation data play a decisive role. With the help of standardized methods of earth observation, not only a more sustainable forest management can be supported, but also the carbon content and the emission reduction potential of forests and reforested areas can be estimated. Due to the full coverage of the inventory, it is possible to comprehensively supplement the information from forest inventories.

Various EO approaches for inventory and management of forests globally have already been developed. In particular, mapping and monitoring of deforestation and forest degradation is well supported by EO. The development of EO data processing platforms like ESA's Forestry TEP (Forestry Thematic Exploitation Platform) or visualization platforms such as GFW (Global Forest Watch) for forest monitoring, are providing EO data applications. In this context, satellite imagery, through their high spatial resolution, can be used to map the extent and type of large forest areas worldwide and to assess the status and productivity of forest stands. Therefore, Earth observation is one of the most cost-effective solutions for remote study areas. Also, the high temporal resolution offered by systems such as the Sentinels is ideal for monitoring changes caused by deforestation and forest degradation over time.

Platforms like Forestry TEP and GFW aim to promote the use of EO data in the forestry sector, by developing new and innovative solutions that leverage the information provided by satellite imagery. Users are also provided with support to forestry professionals, researchers, and policymakers, helping them to make informed decisions on forestry management and policy. Countries can use these platforms and take advantage of the freely accessible EO data for a simplified tracking of mentioned aspects on global and national level and therefore can massively support reporting, pursue and achieve the marks for SDG 15.2.

To monitor and track any form of forest degradation or forest loss, one of the most common data sources are Sentinel-2 and Landsat data. With a resolution of 10m - 30m, these data offer sufficient resolution to detect deforestation both globally and nationally. In addition to the possibility of comparing forest stands at two different points in time, the short revisit cycle of especially Sentinel-2 is suitable for mapping processes of forest changes and it increases the probability of acquiring cloud-free observations. In general, it should be noted that in a large proportion of cases, local forest inventory data are necessary to make conclusive comparisons.

By tracking the extent and impact of timber harvesting or forest disturbances, EO is able of providing valuable information for sustainable forest management. Also, it can be used to support the tracking of wood products from the forest stands to the market. Several EO value-adding companies are working on the development of platforms for detecting deforestation in the context of deforestation-free supply chains. These platforms make often use of time-series data from Sentinel-1 or Sentinel-2 satellites, local expertise and use artificial intelligence to map deforested areas and alert local authorities. Using these platforms, deforestation events can also be predicted by taking into account factors such as land-use change and pattern recognition.

Another interesting aspect of EO technologies is that they can support the large-scale assessment of tree heights and biomass, which are critical factors in determining a forest's carbon stocks. Via specific allometries, EO-based information can provide estimates of biomass and consequently carbon stocks for large forest areas. This allows assessments of the effects of deforestation and forest degradation on carbon fluxes and monitoring of the effectiveness of strategies to maintain and restore forests as carbon reservoirs. In this approach, however, it is necessary to have sufficient information about the local tree populations, such as stand density or specific mass properties of the native tree species, to be able to calibrate the applied allometries. However, to calibrate these models at the country level, field plots are still necessary [RD57].

In particular, a meaningful combination of the above-mentioned application areas of EO and the possibilities of AI-based approaches, opens up a wide range of opportunities to monitor forest areas continuously at high resolution worldwide. It should be noted, however, that the possible applications can vary from country to country. It must always be taken into account that in many application areas combinations of local field data and EO are still needed to generate insightful results. Depending on local conditions, capacities, and data structures, applications must be designed so that they can be adapted to individual needs.

4.2 Advances in Digital Technology

Eliminating poverty, securing world food supplies, more education and combating climate change – the United Nations Sustainable Development Goals can only be achieved with real leaps in development. Digitization influences all aspects of public and private life and connects all areas such as production, transport, science, administration and politics. Due to this increasing global networking, digital transformation offers a unique opportunity to achieve development goals more efficiently and effectively with new technologies and approaches. At the same time, the digital transformation is disrupting the economy and society and bringing with it new risks.

Digitisation enables development through better inclusion, efficiency and innovation. At the same time, the possibilities of digitization also pose social risks: control, inequality and (power) concentration can be accelerated and strengthened by digitization. In the context of sustainable development, which is often sector-specific and bilateral, a number of digital applications and methods are being implemented within the framework of individual projects, but the cross-sectoral and global significance of digital change and the associated potential for sustainable development have not yet been fully exploited.

4.2.1 Need for data-driven solutions

Climate change is increasingly posing a threat to mankind due to changing environmental conditions. The Intergovernmental Panel on Climate Change published the 6th assessment report, according to which the effects of climate change in the form of extreme weather events (heat waves, heavy rainfall, long dry periods, etc.) is irreversible despite a possible 1.5 degree target with net zero emissions by 2050. Climatic parameters have been observed, recorded and analysed for about 200 years. Through dedicated analyses of large amounts of data using extensive computing power, the complex relationships between climatic changes and their effects on the environment can today be better resolved. The exponential increase in the performance of computers and the networking of these enable more and more detailed, complex and multidimensional analyses of data and the generation of information on climate change. With the use of high-performance technologies such as cloud computing and the use of artificial intelligence, a new dimension of data analysis for end users has been achieved in the last years.

The evaluation of multidimensional data is therefore a key to capturing the dimensions of land surface change. The use of satellite data has become indispensable in analysis and represents a central technology. In 1972, a new era of land surface monitoring was heralded by the launch of Landsat-II and the use of the first computer-based analyses of this information towards meaningful information. For the first time it was possible to observe land dynamics objectively and over a longer period of time and thus draw conclusions about changing environmental conditions and human influence.

A revolution is taking place in the field of Earth Observation (EO). Data availability, both in type and quantity, is growing at an astounding rate both in the public domain and through an ever-expanding fleet of satellites operated by new commercial players. With the constellation of the Sentinel satellites and an open data policy, the European Copernicus program is one of the most important actors in this field. In 2019 alone, the volume of open satellite data (from Landsat, MODIS and the Sentinel -1, -2 and -3 missions) was about 5 PB, with only a small part of the available data often being used due to a lack of storage and processing capacities by users and valued [RD58]. Access to high-speed cloud computing is making it possible to perform calculations on this data that were thought impossible just a decade ago.

This ever-growing satellite infrastructure, together with efficient data processing capacities, can drive digital transformation and automation initiatives for sustainable development. However, these new technologies also require new levels of complexity in data processing. In order to be used efficiently, everyone involved should be able to i) process data in significantly larger quantities than before, ii) identify and use suitable cloud infrastructures, iii) integrate methods of artificial intelligence.

4.2.2 Cloud-based analytic platforms

In recent years, due to the increasing demand for cloud-based spatial data infrastructures (SDI), there have been various developments in the area of platform solutions as an interface between users and IT systems. These should enable and promote access, storage, exchange, sharing and analysis of large amounts of geodata. A fundamental principle of these platform solutions is to bring users to the data and tools, instead of data to the users, which then have to be analysed with special software.

There are two main scenarios regarding the use of cloud-based EO data analytic capacities for SDG monitoring. On the one hand, platforms can be used to carry out national analyses of EO data, which are mostly very individual solutions that are tailored to the specific requirements of the country (often influenced through other national monitoring needs). In most cases, these have a high degree of specialisation and can only be transferred or scaled to a limited extent. On the other hand, there is a need for repetitive analyses of large amounts of data (e.g. monitoring) at trans-national level. For such a scenario, a stronger generalization of the solution is essential so that it can be applied globally. That is why a clear definition of the purposes, sectors and stakeholders for which a cloud-based EO data analytic platform is needed, since real added value only arises through thematic and user scaling of the application.

4.2.3 Requirements for an effective implementation of EO platforms in SDG monitoring

The requirements for using and scaling EO data analytic platform solutions can be divided into four main components:

- Scalable cloud capacities

The use and scaling of cloud capacities (infrastructure as a service) is primarily limited by the use of financial resources, since existing cloud infrastructures are technically easily scalable, but lead to increased usage costs from certain cloud resources. The existing cloud services have different cost structures, which in most cases are based on the processing capacities (virtual CPU and RAM) and the data storage. The advantage of this is that users usually only have to pay for what is actually used (possibly additional basic costs). Thus, the number of users and the scope of the individual analytics determine the costs incurred. This can lead to very volatile costs, which requires a flexible financing structure on the user side of SDG monitoring.

- The hosting of the service and its maintenance

For sustainable and long-term use, hosting and maintenance of the platform solution (Platform as a service (PaaS)) must be guaranteed. It is fundamental to consider the control structures behind the platform services, in order to avoid choosing solutions that have an expected end of maintenance or even end of operation. This poses a risk, especially in the case of project-related and time-funded PaaS developments. The descriptions of the operator concepts are also often very vague and only allow limited conclusions to be drawn about this factor. Possibilities for minimizing this risk are the selection of already established providers.

- Necessary EO & IT expertise

Depending on the complexity of the EO data analysis, different levels of geodata expertise are essential for using EO data analytic platforms. Although there are already platform services for some applications that are easy to automate that offer very simple and user-friendly user interfaces, these already require a certain basic knowledge of geodata handling and processing. The effort required to train users sufficiently to use such a platform must be estimated at the beginning of a conceptual design of an SDG monitoring system. The majority of applications are currently still based on more complex geodata analytics using multidimensional data, the development and use of which require a high level of EO and geoinformatics expertise. This is why the necessary EO and geodata expertise should not be underestimated in order to minimize user-related uncertainties. A precise definition of the user group is required in order to optimally design platform solutions for SDG reporting, which will in turn stimulate their global use and their institutionalization.

- The (further) development capacities

The possibility and potential of future further development of the SDG monitoring system is also an important prerequisite for the long-term use and scaling of platform solutions. On the one hand, future technologies and new types of data should be easy to integrate in order to further strengthen established methods. On the other hand, it should be possible to develop new solutions based on the platform technology in order to expand the relevance of the platform solution across different SDG indicators or even in regard to future new indicators.

4.2.4 Big data and AI

Besides the huge amount of satellite data, a large number of organisations make geodata publicly available with a wide range of topics. Some of these data can be combined with EO data or products derived from it in order to generate SDG-specific geoinformation products with increased informational value. Users have to handle a very large amount of geodata with different temporal and spatial characteristics. This requires analysis and data processing methods that can process this multidimensional data, as well as interfaces and data standards to easily obtain and integrate the data. The standards proposed by the Organisation for Standardization (ISO) and the Open Geospatial Consortium (OGC) are essential to ensure geospatial interoperability between GDIs of global or national agencies and institutions [RD58]. The Open Geospatial Consortium (OGC) is an international consortium of more than 500 companies, government agencies, research organisations and universities that aims to make geospatial (location) information and services FAIR - Findable, Accessible, Interoperable and Reusable [URL72]. In December 2021, OGC released the "Best Practice for Earth Observation Application Package" which includes recommendations for application and package design, container and data interfaces for data stage-in and stage-out strategies [URL73].

In order to best exploit this huge amount of multifactorial data, methodologies of artificial intelligence (AI) offer a big opportunity also for the SDG monitoring. One part of AI, machine learning, has long played an important role in data analysis in Earth observation. Trained decision trees, ensemble learning methods such as random forests or regression-based methods are now standard methods in EO data analysis. However, the sub-area of deep learning (DL) has so far been used very little to derive new information products from EO data. Deep learning has great potential, especially for cloud-based evaluation methods with a high degree of automation, since huge amounts of data and the necessary IT capacities are now available to extract important geoinformation from these amounts of data using deep neural networks. Deep learning is becoming increasingly important in earth observation and will improve the efficiency of existing spatial data analyses. Ma et al. provide a good overview of previous deep learning developments and applications in earth observation [RD59] and Zhu et al. [RD60] in their review articles. The use of DL methods also requires a certain methodological competence, since DL is more suitable for some areas than for others, and the solutions are specifically sought if they lead to better information quality or more efficient data processing compared to established methods. DL has a very large potential for EO data analysis if these tools are used properly. Until a certain DL method is established and can be used (inference), there is a large data requirement for training and testing the neural networks (training). This initially involves a great deal of effort to generate this training and test data. However, there are also more and more repositories that provide training data for certain areas, or tools that are suitable for efficiently collecting training data. The Radiant MLHub of the Radiant Earth Foundation and the Collect Earth Online tool (FAO, NASA, USAid etc.) should be mentioned as relevant repositories/tools in this context.

5 Requirements Specification

5.1 SDG Requirements

Below is a list of requirements pertaining to the SDG reporting on Goal 15 Targets 15.1 and 15.2

- The indicators should be selected based on five criteria: **relevance** to monitoring the achievement of the SDGs; **statistical adequacy**; **timeliness**; **data quality** and **coverage**.
- Indicators for tracking progress towards sustainable development are intended to be used by policy makers. Therefore, they need to be **simple** and **understandable**. The cause-and-effect dynamic must be comprehensible.
- The indicators for tracking progress towards sustainable development must be **reproducible**. They need to have a clear and unambiguous methodology without any statistical randomness.
- The indicators must be **transferable** across ecosystems and geographical regions to enable global tracking of progress towards sustainable forest management.
- The indicators must be temporally and spatially **robust**, that is they need to have the comparable ranges.
- Tracking **specific** aspect of sustainable development. It must be clear which aspect of sustainable development (environmental, social, economic) the indicator is being tracked. If an indicator is tracking the progress towards more than one aspect of sustainable development, it should acknowledge the feedback effect between the three aspects.

5.2 Technical Specification and Data Requirements

Technical requirements, in the context of the proposed EO solutions, include the information content/description of the output products, target accuracies, spatial and temporal resolutions, spatial coverage and timeframe. Further technical requirements include data formats and file types for the input data and the output products.

A list of EO solutions was offered to be addressed in this project, supporting the established SDG indicators 15.1.1 and 15.2.1 reporting on one hand and proposing new additional metrics on the other (Figure 16 left and right block).

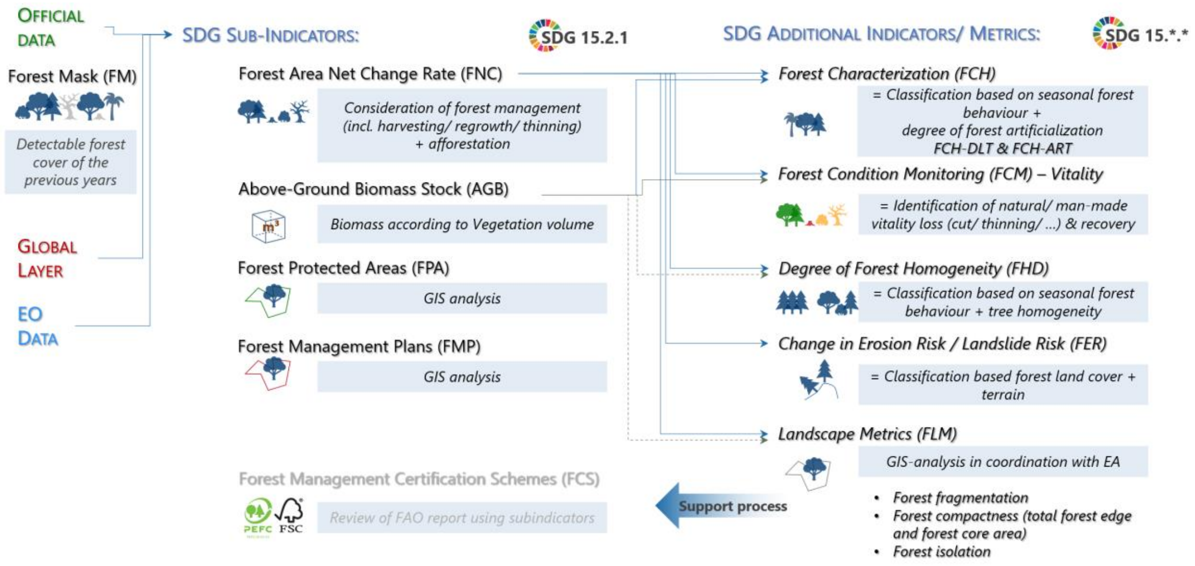

Figure 16: Proposed EO solution portfolio. Left: sub-indicators required in the SDG reporting process; Right: additional metrics suitable to be supported with Copernicus data and suitable as potential add-on of the reporting process

This product portfolio has been presented to the Early Adopters and will be the portfolio considered within further discussions with them in order to adapt it to their individual needs as well as to identify common requirements. As the requirements depend on feedback from the Early Adopter, they will be further evolved as the project progresses. This will mainly concentrate on the activities related to the proof of concept. The status of these considerations based on the outputs of the Co-Design Living Lab is briefly outlined below in Table 23, focusing on the preliminary service specification and the data requirements.

Table 23: EO solutions portfolio with their preliminary technical specifications and data requirements

EO solution	Technical Specification	Data requirements
Forest Mask (FM)	• Product: Raster Layer showing the extent of forest stands, which is regularly updated • Reporting: Area in ha • Analysis: Using existing national inventories, other EO-based data sets (e.g. ESA WorldCover), or processed Sentinel data	• EO data: Sentinel-2 • Open products: depending on country • User data: previous masks
Forest Area Net Change Rate (FNC)	• Product: Rate of forest area change, based on updated forest masks • Reporting: area in ha and change maps • Analysis: GIS-based analysis of two or more forest masks from different years or active image-to-image change detection	• EO data: Sentinel • Open products: depending on country • User data: FM, Tropical Moist Forest Layer (multi-temp)
Above-Ground Biomass Stock (AGB)	• Product: Raster indicating the estimated above ground biomass (AGB) of forest stands in tons/ ha • Reporting: metric tons and maps showing biomass variability • Analysis: various TIER levels, depending on available data	• EO data: various • Open products: Global Biomass estimates (GEDI) • User data: existing maps or forest inventories, tree specific allometries

EO solution	Technical Specification	Data requirements

Forest Protected Areas (FPA) & Forest Management Plans (FMP)	• Product: Intersection from Forest Mask with protected areas and forests with management plans
	  • MMU of 0.5 ha, GIS layers
	• Reporting: statistical summary
	• Analysis: geometric intersection between FM and protected areas / forests with management plans
	  • Suitable GIS data must be available
	  • Breakdown of the enhanced sub-indicators 1 (FNC) & 2 (AGB)
		• EO data: none
		• Open products: World Database on Protected Areas (WDPA), Other Effective Area-Based Conservation Measures (OECM)
		• User data: Protected areas, Forests with management plans

Forest Characterization (FCH)	• Product: classifications / artificialization indexes
	  • MMU of 0.5 ha, raster layer
	• Reporting: statistical summary
	• Analysis: seasonal forest behaviour and degree of forest artificialization
	  • Time series of optical imagery to discriminate between tree types
	  • Texture indexes used for assessing the degree of forest artificialization
	  • SAR imagery can be used as a complement to support the analysis
		• EO data: multispectral (Sentinel-2, Landsat) and SAR (Sentinel-1) - Time series data
		• User data: Possibility of training datasets

Forest Condition Monitoring (FCM) – Vitality	• Product: Discrete Forest condition changes (time intervals to be defined)
	  • MMU of 0.5 ha, raster layer
	• Reporting: change frequency, change area (statistics)
	• Analysis: tracking vitality and condition changes
	  • Detect vegetation decrease/ disturbance and increase
	  • Establish average vegetation vitality benchmark (timeseries)
	  • Change detection between two consecutive years
		• EO data: multispectral (Sentinel-2, Landsat)
		• Consistent ARD (e.g. GLAD)
		• Time series data (previous and recent reporting period)
		• User data: ground truth, inventory data

Degree of Forest Homogeneity (FHD)	• Product: homogeneity index
	  • MMU of 0.5 ha, raster layer (Range: 0 (homogeneous) - 1 (heterogeneous))
	• Reporting: statistical summary
	• Analysis: calculate homogeneity of forests
	  • similarity measure for each pixel and its neighbourhood based on e.g. spectral signatures, seasonal behaviour, textures, brightness values and AGB
		• EO data: multispectral (Sentinel-2)
		• Time series data for spectral signatures
		• Suited spatial resolution to derive textures, spectral signatures
		• User data: national inventories, ground truth & other data

Change in Erosion Risk / Landslide Risk (FER)	• Product: classifications / indexes • MMU of 0.5 ha, raster layers (5 classes: 1 (Very Low), 2 (Low), 3 (Moderate), 4 (High), 5 (Severe)) • Reporting: statistical summary	• EO data: multispectral (Sentinel-2, Landsat), Copernicus Global DEM • Time series data • Open products: LULC, DEM, ESDAC datasets (JRC)

EO solution	Technical Specification	Data requirements

	• Analysis: soil erosion risk / landslide susceptibility and their evolution
	  ◦ Particularly relevant in forests subject to disturbances: loss of trees or reforestation/ afforestation, after natural disasters (fires or wind throw events)
	  ◦ Based on the (R)USLE model (soil erosion risk) and Landslide Susceptibility Index (LSI)
	  ◦ Methodology to be adapted according to layers availability
		• User data: national DEM data, geological/ soil information

Landscape Metrics (FLM) 	• Product: landscape metrics ◦ MMU 0.5 ha • Reporting: statistical summary • Analysis: measure forest fragmentation/ landscape composition: (a) edge metrics, (b) core area metrics, (c) shape metrics, (d) isolation metrics and/ or other to be defined	• EO data: EO4SDG-products • Open products: current binary forest mask • User data: forest masks

Additionally, the EO solutions pose requirements to the working environment and the infrastructure that is used for product generation:

- The environment to produce indicator maps must be scalable,
- The environment must be able to handle large datasets that are needed for processing large geographical areas.
- The environment should also have means to protect sensitive data from unauthorized access.

Furthermore, the objective to support deployment of the EO solutions in various infrastructures poses technical requirements to development of the solutions. In particular, the individual processing steps should be designed so that they consume their inputs and produce their outputs in a non-interactive command line processing mode. This is a minimum requirement to support transferability of the solutions; individual service platforms will pose their specific requirements as outlined above.

5.3 User Requirements

The following list provides an overview of the main end-user requirements, emerged from the different user engagement activities organised in the project. Early Adopters require

- appropriate monitoring tools for assessing forest condition and homogeneity. These are important for assessing risk levels affecting extent and characterization of the forest cover.
- appropriate tools to evaluate the soil erosion and landslide risks, especially in mountainous areas and in respect to increased frequency of extreme weather events during the rainy season.
- to learn and evaluate the potential of EO services to aid forest monitoring.
- harmonized EO services, which can compile multidisciplinary sets of data, automatized, user-friendly, and simple to use. The latter two are especially relevant given that many forestry end-users (especially small forest owners) often lack technological knowledge and expertise.
- services whose outputs are critically and scientifically evaluated and validated.

- see EO-based services as a critical technological innovation for monitoring forest condition, while reducing on-site forest visits especially in remote areas with no access.

Table 24: EO products requested by the Early Adopters and their potential implementation on Test Site and National Demonstrator level

EO solution	Vietnam		Germany (Hessen)		Brazil		Colombia		Ethiopia		West Africa	
T - Test Site D - Demonstrator	T	D	T	D	T	D	T	D	T	D	T	D
Forest Mask	X				X	X	X	X	X	X	X	
Forest Net Change	X				X	X	X	X	X	X		
Above Ground Biomass	X								X			
Forest Protected Areas & Forest Management Plans					X						X	
Forest Characterisation												
Forest Condition Monitoring			X	X	X		X		X		X	
Forest Homogenity			X								X	
Forest Erosion Risk / Landslide Risk	X				X		X				X	
Forest Landscape Metrics	X		X									

5.3.1 Vietnam

As an organisation focused on managing country's forest and performing monitoring activities and implementing the national forest strategy, FIPI is interested adopting RS based tools. FIPI sees EO-based services as a critical technological innovation for monitoring forest condition, while reducing on-site forest visits especially in remote areas with no access.

In respect to the problems and challenges of FIPI listed in chapter 3.1.3 the users in Vietnam can benefit from:

- Tools for monitoring the state of natural forests
- Tools for tracking progress towards implementation of the national forest strategy
- Tools for estimation and monitoring of total forest cover
- Tools for the large-scale estimation and monitoring of above and below ground biomass, particularly in mangroves.
- Appropriate tools to evaluate the risk of forest fire.
- Appropriate tools to evaluate erosion and landslide risk, especially in limestone regions.

5.3.2 Germany (Federal State Hessen)

With reference to the problems and challenges of the Hessian Forests and their management listed in chapter 3.2.3, EO products can be an important complementary tool to address them. In discussion with the Early Adopter HessenForst, some user-requested use cases of EO methods were identified. Based on the discussed user needs the following user requirements can be derived:

- The user is interested in an EO service that can detect forest damages caused by natural influences like storms, pests and drought.
- The user is interested in an EO service that can provide a meaningful vitality indicator for all German forest types to improve forest condition monitoring.
- The user is interested in a EO service that contributes to a better understanding of the biodiversity and growth dynamics of trees in open spaces to support efficient reforestation.

5.3.3 Brazil

With reference to the problems and challenges of the Amazonian forest, EO products can be helpful to the users in a range of applications, such as:

- The user is interested in an EO service that can detect forest damages caused by deforestation and human influence on the forest
- The user is interested in an EO service that can provide a meaningful vitality indicator to improve forest condition monitoring.
- The user is interested in an EO service that contributes to a better understanding of biodiversity and tree growth dynamics in a natural environment

5.3.4 Colombia

With reference to the problems and challenges of Colombian Forests, EO products can be an important complementary tool to help users solve the problems they encounter:

- The user is interested in an EO service that can detect forest damages caused by deforestation and human influence on the forest
- The user is interested in an EO service that can provide a meaningful vitality indicator to improve forest condition monitoring.
- The user is interested in a EO service that contributes to a better understanding of the biodiversity and growth dynamics of trees under strong oceanic influence

5.3.5 Ethiopia

The Early Adopter from Ethiopia has chosen the following products to be generated for some study areas that are explained below. They also indicated the interest in a potential demonstration at a national scale.

5.4 Product Validation Requirements

Validation is the process by which the accuracy and consistency of satellite-derived land products are evaluated and associated uncertainties are quantified. Product accuracy is assessed by comparison with independent data sources such as ground-based in situ measurements or local maps derived from ground data and higher resolution satellite data. Additionally, inter-comparison with other equivalent satellite products provides useful insights as to where and when data sets agree or disagree and consequently identifies problem areas where additional efforts are needed. Validation is mandatory for scientific studies where data assimilation is used to combine observations; ecosystem and climate modelling; and the provision of information for reporting issues within international conventions.

Equally important, validation activities need to be coordinated at the international level and in close collaboration with the Early Adopters in order to reach the necessary consensus from the community, establish common practices and standards while ensuring a traceable and transparent process, reflected in a validation protocol recognized by the international community.

The Validation Protocol aims at providing a common framework for assessing and reporting the accuracy of the EO4SDG products and evaluate the Early Adopters' acceptance of these products. The validation and Early Adopters' assessment are essential for providing high-quality products that are accepted and applied by the community. While a standardized approach recognized by the international community for validating large area products is not yet available, significant experience regarding validation concepts and procedures have been developed in other communities, and the current validation task will be based on the lessons learned from these previous projects. Ultimately, the accuracy assessment is aimed to build international confidence in the EO4SDG products and their adoption by the community. The Validation Protocol will provide common metrics and procedures to report uncertainty statistics and maps in a standardized way, allowing direct comparison among the products (e.g. 95% Confidence Interval, Coefficient of Variation, etc.).

The assessment of input data quality will be based on internal quality checks, external validation measures and metadata information of the used data sets. Therefore, a comprehensive list will be generated including all relevant validation parameters to assess the quality and made freely available via the platform (F-TEP) to allow usage for all potential users.

The identification of error sources for each product will consist in checking the following parameters:

- Accuracy of remote sensing data (spatial error, spectral error)
- Accuracy of additional datasets
- Accuracy of ground data
- Spatial mismatch between ground and remote sensing data
- Temporal mismatch between ground and remote sensing data
- Prediction error of the applied model (or uncertainty of the algorithm)

The common framework consists of four main components that jointly lead to the achievement of the validation objectives:

- Uncertainty assessment
- Independent validation
- Maps inter-comparison
- User assessment

Validation objectives:

- Robust assessment of product accuracy and understanding error sources
- Build EA confidence for model applications
- Increase the acceptance and legitimacy of the products within the international community
- Identify recommendations for further improvement of the products
- Take into account error propagation
- Independent validation (validation metrics: bias, standard deviation of the error, 95% confidence interval of the mean error, RMSE and relative RMSE, etc.)
- The basis for assessing the accuracy of categorical maps (e.g. Forest Mask) is the confusion matrix.

The validation of SDG sub-indicators will be based on qualitative and quantitative measures, following the best practices established by several expert authors in the validation domain, and the practices defined in the standards ISO 19157, ISO 2859 and ISO 3951-1:2005. The protocol will also differ according to the nature of the EO products: raster products such as continuous indexes, masks or classifications (FHD for instance) or vector/GIS layers (like FMP or FPA).

For instance regarding AGB product, according to the publication [RD61] a standardized accuracy assessment will be carried out for all regional AGB maps by making use of independent reference data. In [RD61] the assessment was based on stratifying the reference AGB into contiguous ranges of values and quantifying the estimation bias, the standard deviation of the error and the Root Mean Square Error (RMSE) within each range. The selected ranges varied with test site, depending on the maximum value of biomass for the site and the need to have a sufficient number of reference data within each range. This procedure is envisaged to adapt to the situation of the generated AGB maps and to implement as best as possible under consideration of the availability of suitable reference data sets.

In general, thematic accuracy aims to reach a minimum target (to be determined according to the maturity level of the product) and positional accuracy based on input EO imagery and its specifications. Thematic accuracy can be higher in distinct locations and specific parameter settings. Nevertheless, considering the whole objective of the project and in general its worldwide application some minimum accuracy values must be achieved.

The quality assessment will be implemented through statistically sound sampling approaches, in order to be efficient while guaranteeing that the inspection results can be extrapolated to the population at a certain level of confidence and within a controlled margin of error. The sampling strategies, which include sampling protocols, size and units, are based in the expert knowledge of the team together with the best practices established in the reference standards mentioned above.

Two different sampling protocols will be used due to appropriateness depending on the data quality elements to be evaluated: Area guided sampling for the completeness; and stratified random sampling for the thematic accuracy of the classification layers. The sample size calculation also differ for the different strategies.

Area guided sampling strategy

A simple feature-guided random sampling does not account for heterogeneity of features. This is because the most represented features will have higher probability of being selected, and very often these are of the same feature class and can be found following particular spatial patterns. On the other hand, a stratified feature-guided random sampling could guarantee the heterogeneity of the sample regarding features classes representation. However, it would still not account for the several different patterns of features distribution in an area of interest. Furthermore, a feature guided sampling would put the focus on the extracted features and not on the universe of disclosure (i.e. "ground truth") thus biasing towards more commission errors and less omission errors. To deal with the referred challenges, when evaluating completeness of vector data, an area-guided sampling through the definition of lot areas randomly selected is applied to account for the heterogeneity of features distribution while removing bias in favour or against commission and omission errors. For every lot the image analysts interpret the universe of disclosure ("ground truth") and compare it with the map to determine commission and omission errors and as well to measure the positional accuracy. The total number of lot areas will be determined by the number of features which are necessary to evaluate to reach the minimum sample size for a given group of layers, based on Table 25.

For measuring positional accuracy (relative or internal accuracy), points are deterministically selected for establishing coordinate values accepted as the "ground truth" – this shall be done without looking to the map. After selection, these points are reviewed to determine the respective feature instances from the map to measure the difference in position. To follow a probabilistic approach, this needs to be done for every lot inspected for the commission and omission assessment, furthermore allowing to improve efficiency of the quality control task. If the number of samples is sufficient, the positional accuracy may be determined. If not, the lot inspection must carry on for positional accuracy until the minimum sample size is achieved. The RMSE will be calculated and compared with the established requirements for determining if the map's relative or internal accuracy is acceptable.

Table 25: Statistical values based on the hypergeometric distribution for testing of number of conforming/non-conforming items for a significance level 95 %

Population size		p_0 =	0,5 %	1,0 %	2,0 %	3,0 %	4,0 %	5,0 %
From	To	Sample size (n)	Rejection limit					
1	8	All	1	1	1	1	1	1
9	50	8	1	1	1	2	2	2
51	90	13	1	1	2	2	2	3
91	150	20	1	2	2	3	3	4
151	280	32	1	2	3	3	4	4
281	400	50	2	3	3	4	5	6
401	500	60	2	3	4	5	6	7
501	1200	80	3	3	5	6	7	8
1201	3200	125	3	4	6	8	10	11
3201	10000	200	4	6	8	11	14	16
10001	35000	315	5	7	12	16	20	23
35001	150000	500	6	10	16	23	28	34
150001	500000	800	9	14	24	33	42	51
> 500000		1250	12	20	34	49	63	76

Stratified random sampling

The thematic accuracy assessment will be carried for the wall-to-wall thematic features and will be based on a stratified random sampling. The protocol will rely on the creation of a thematic reference layer by image analysis of a stratified random sample layer. This layer will be cross-compared to the area features of the classification category of the map to produce a confusion matrix and calculate the misclassification rate (overall accuracy).

The sampling design is the protocol used to spatially distribute the sampling units that constitute the reference database [RD62]. A probability sampling design is one in which the inclusion probabilities are known for all elements in the sample and are nonzero for all elements in the population [RD63]. Statistically rigorous designs contribute to scientifically defensible accuracy assessments, and therefore such designs must be used because of their objectivity.

The stratified random sampling scheme seems thus to be the most adequate to ensure that the map holds an adequate number of sampling units required to estimate its accuracy. The stratified sample distribution will be weighted by the different feature classes to ensure that the map accuracy is based on the adequate test of each feature class.

The determination of the sample size will follow the work of reference authors of [RD64], [RD65], [RD66] that have used an equation based on the binomial approximation to the normal distribution to estimate the appropriate sample size for the accuracy assessment of thematic classification products. These authors state that this approach is statistically sound for estimating the sample size needed to compute the overall accuracy of a classification or even the accuracy of a single class. Based on these authors, the sample size required to estimate the overall accuracy of the map within a certain precision, is estimated as follows:

$$\eta = \left(\frac{Z_{1-\alpha/2}}{d} \right)^2 \rho(1-\rho)$$

Where:

η – Sample size
α – Significance level
d – Absolute precision
ρ – probability of belonging to the map class

Note that 0.25 is the maximum value of $\rho(1-\rho)$ that corresponds to an equal chance of the sampling unit being either correctly or wrongly classified.

To perform the classification accuracy assessment, it is necessary to compare the results of the map with the reference classification that is usually summarised in an error matrix (contingency table or confusion matrix). Each cell entry represents the number of sampled units; usually map categories correspond to the matrix rows and reference categories correspond to the matrix columns. The confusion matrix provides a visual overview of the accuracy results. The overall thematic accuracy for the area features of the classification layers will be calculated. The overall accuracy is the overall proportion of correctly classified reference sampling units (corresponding to the sum of the diagonal elements of the matrix divided by the total number of units in the sample).

The following table shows the validation scheme for the provided SDG sub-indicators. Validation task will be executed by partner(s) independent from production / specific service generation to guarantee the four-eyes-principle.

Table 26: Validation scheme of SDG sub-indicators

Service element	Qualitative measures	Quantitative measures	Dependencies (other services)	Acceptation criteria
Forest Mask (FM, SDG 15.2.1)	User feedback form	• Cross-comparison and/or Classification analysis based on ISO 19157: • i) Completeness, ii) Logical consistency, iii) Positional accuracy, iv) Thematic accuracy	• Access to inputs (imagery, forestry datasets) • National/ regional definition of Forest vs. SDG relevant forest definition	• Positional accuracy: <=2 pixels plus positional accuracy of the sensor • Thematic accuracy: TBD
Forest Area Net Change Rate (FNC, SDG 15.2.1 (1))	User feedback form	• Cross-comparison and/or Classification analysis based on ISO 19157: • i) Completeness, ii) Logical consistency, iii) Positional accuracy, iv) Thematic accuracy	• Access to inputs (imagery, forestry datasets)	• Positional accuracy: <=2 pixels plus positional accuracy of the sensor • Thematic accuracy: TBD
Above-ground biomass stock (AGB, SDG 15.2.1 (2))	User feedback form	Cross-comparison based on ISO 19157: i) Completeness, ii) Logical consistency, iii) Positional accuracy, iv) Thematic accuracy	• All other AGB sources (see Table 3 of Offer) • In-situ measurements (EA, national)	• Provision of uncertainty layer to geolocate regions of high/ low degree of certainty • Positional accuracy: <=2 pixels plus positional accuracy of the sensor
Forest protected areas (FPA, SDG 15.2.1 (3))	EA indications on best database (if existing)	Cross-comparison based on ISO 19157: • i) Completeness, ii) Logical consistency	• Existence of national / global FPA GIS layers	• Verification with/by EAs • All official or non-official data sets which could be verified by EAs or respective entities
Forest management plans (FMP, SDG 15.2.1 (4))	EA indications on best database (if existing)	Cross-comparison based on ISO 19157: • i) Completeness, • ii) Logical consistency	• Existence of national / global FMP GIS layers	• Verification with/by EAs • All official or non-official data sets which could be verified by EAs or respective entities
Forest Characterization / Dominant Leaf Type (FCH-DLT)	User feedback form	• Cross-comparison and/or Classification analysis based on ISO 19157: • i) Completeness, ii) Logical consistency, iii) Positional accuracy, iv) Thematic accuracy	• Access to inputs (imagery, forestry datasets)	• Positional accuracy: <=2 pixels plus positional accuracy of the sensor • Thematic accuracy: TBD

Service element	Qualitative measures	Quantitative measures	Dependencies (other services)	Acceptation criteria
Forest Characterization / Artificialization index (FCH-ART)	Report on index logic by visual interpretation of samples	• Cross-comparison and/or Classification analysis based on ISO 19157: • i) Completeness, ii) Logical consistency, iii) Positional accuracy, iv) Thematic accuracy	• Dynamics of forests (TMF, GFW)	• Positional accuracy: <=2 pixels plus positional accuracy of the sensor • Thematic accuracy: TBD
Forest Condition Monitoring (FCM)	Report on index logic by visual interpretation of samples	• Cross-comparison based on ISO 19157: • i) Completeness, ii) Logical consistency, iii) Positional accuracy, iv) Thematic accuracy	• Interconnection and correlation with climate trends	• Positional accuracy: <=2 pixels plus positional accuracy of the sensor • Logical cross-validation with (at least qualitative) in-situ data (if available)
Degree of Forest Homogeneity (FHD)	Report on index logic by visual interpretation of samples	• Cross-comparison based on ISO 19157: • i) Completeness, ii) Logical consistency, iii) Positional accuracy, iv) Thematic accuracy	• Cross-validation with FMP and FCH-ART data sets	• Positional accuracy: <=2 pixels plus positional accuracy of the sensor • Logical cross-validation with (at least qualitative) in-situ data (if available) • Thematic accuracy: TBD
Change in Erosion risk/ landslide risk (FER)	Report on index logic by visual interpretation of samples	• Cross-comparison based on ISO 19157: • i) Completeness, ii) Logical consistency, iii) Positional accuracy, iv) Thematic accuracy	• Availability of FCM layer and up-to-date LULC for LSI calculation	• Positional accuracy: <=2 pixels plus positional accuracy of the sensor • Thematic accuracy: TBD
Forest landscape metrics (FLM)	Report on index logic by analyzing different values of FLM in input imagery	• Cross-comparison based on ISO 19157: • i) Completeness, ii) Logical consistency, iii) Positional accuracy, iv) Thematic accuracy	• Access to inputs (imagery, forestry datasets)	• Positional accuracy: <=2 pixels plus positional accuracy of the sensor • Thematic accuracy: TBD

6 Use Case Realisation

6.1 Test Site

6.1.1 Vietnam

Based on our discussion with representatives of the Forest inventory Institute, an area of interest (AOI) in the the North Central region was chosen due to its diversity in topographic and climatic conditions. The selected test site representative enough for the algorithm trade-off analysis and proof of concept due to bedrock, climatic and topographic variation. The area covers the southern section of the Northern Annamites rain forests ecoregion which spans over the rugged and relatively unexplored northern Annamite Mountains of central Laos and Vietnam. There are high numbers of endemic plant species, and the relative remoteness and isolation of the area supports many rare and endangered animals. Rainfall is somewhat less than the lowland rainforest of the lower elevations in Vietnam, and the temperatures slightly cooler due to the higher altitude.

The test site covers an area of approximately 12300 km² in the central portion of the North Central Region of Vietnam. Administratively the test site covrs the northern portion of Quảng Bình province. The selected AOI contains five of the six eco-regions (Figure 24) present in the area. Particularly it contains the limestone region of Mountain Phong Nha-Kẻ Bàng, including Phong Nha-Kẻ Bàng national park. The difference in bedrock conditions lead to significant difference in the vegetation cover in comparison to other regions. Furthermore, the area contains the southern portion of the Mountainous Area to the west of Thanh Hoa, the delta and coastal sandy dunes, and the hilly terrain located between the latter two. To the south the area covers the northern edge of the mountain range to the West of Binh Tri Thien.

Table 27: Forest ecoregions in North Central Region according to the UN-REDD Forest Ecological Stratification in Vietnam [RD68]

Subregion	Climate	Topography	Soil groping	Forest type
Mountainous Area to the west of Thanh Hoa, Nghe An and Ha Tinh provinces	Tyear: 18-23oC; Ryear: 1100-1400 mm	> 700m	Ferralsols/ Alisols/ Leptosols	Mixed closed humid and medium mountainous tropical evergreen forests / bamboo forests Bamboo forests + mixed timber and bamboo forests
North Central hilly terrain	Tyear: 22-24oC; Ryear: 1600-4000 mm	Low and medium mountains	Acrisols/ Ferralsols/ Leptosols	Mixed closed humid and low mountainous evergreen tropical humid forests/Bamboo forests + mixed timber and bamboo forests/Plantations
Delta and coastal sandy dunes of the North Central Region	T_{year}: 23-25ºC; R_{year}:1600- 3000 mm	Lowland	Fluvisol/ Acrisols/ Gleysols	Plantations
Limestone Mountain Phong Nha – Ke Bang	T_{year}: 20-22ºC; R_{year}:2000- 3500 mm	Medium mountains	Calcisols/ Ferralsols	Mixed closed forests on limestone mountains and valleys/Mixed closed and low mountainous tropical evergreen humid forests
The mountain range to the West of Binh Tri Thien	T_{year}: 18-23ºC; R_{year}:1100- 1400 mm	> 700m	Alisols/ Ferralsol	Mixed closed sub-tropical evergreen humid forests/bamboo forests on high mountains/bamboo forests + mixed timber and bamboo forests.

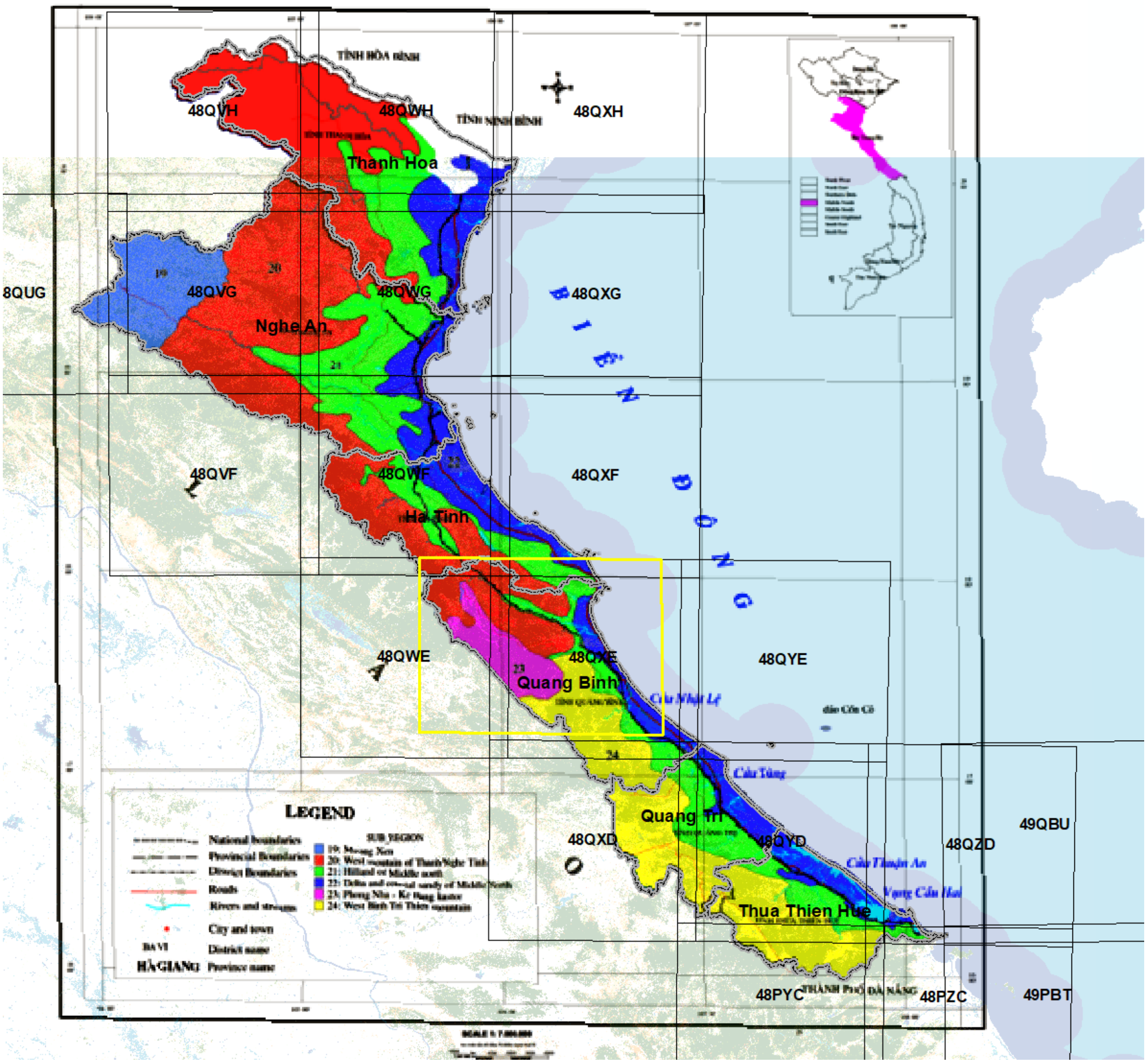

Figure 17: Location of the selected test site (yellow) inside the North Central Region [RD67]. Two Sentinel-2 tiles cover the test site fully. The forest eco-regions are shown in colors. Basemap: JRC Tropical moist forest layer.

The largest vegetation type in Phong Nha-Kẻ Bàng national park is tropical dense moist evergreen forest on limestone under 800 m above sea level. 96.2 % of this national park is covered with forest, 92.2 % of which is intact primary forest. 74.7 % (1104.76 km²) of the park is covered with evergreen tropical wet forest on limestone rocks at the elevation of under 800 m; 8.5 % (126 km²) is evergreen tropical wet forest on limestone rocks at an elevation higher than 800 m; 8.3 % (122.2 km²) evergreen tropical wet forest on soil mounts at the elevation of under 800 m; evergreen tropical wet forest on limestone rocks at the elevation of under 800 m; 0.7 % (10.7 km²) evergreen tropical wet forest on limestone rocks at the elevation of above 800; 1.1 % impacted evergreen tropical wet forest on limestone rocks; 2.8 % (42.12 km²) impacted evergreen tropical wet forest on soil mounts; 1.3 % (1,925) grass, bush on limestone rocks; 2% (29.5 km²) grass, bush on soil mounts; permanent wetland forest: 1.8 km²; rattan and bamboo forest: 1.5 km²; and agricultural plants: 5.21 km²or 0.3 %.

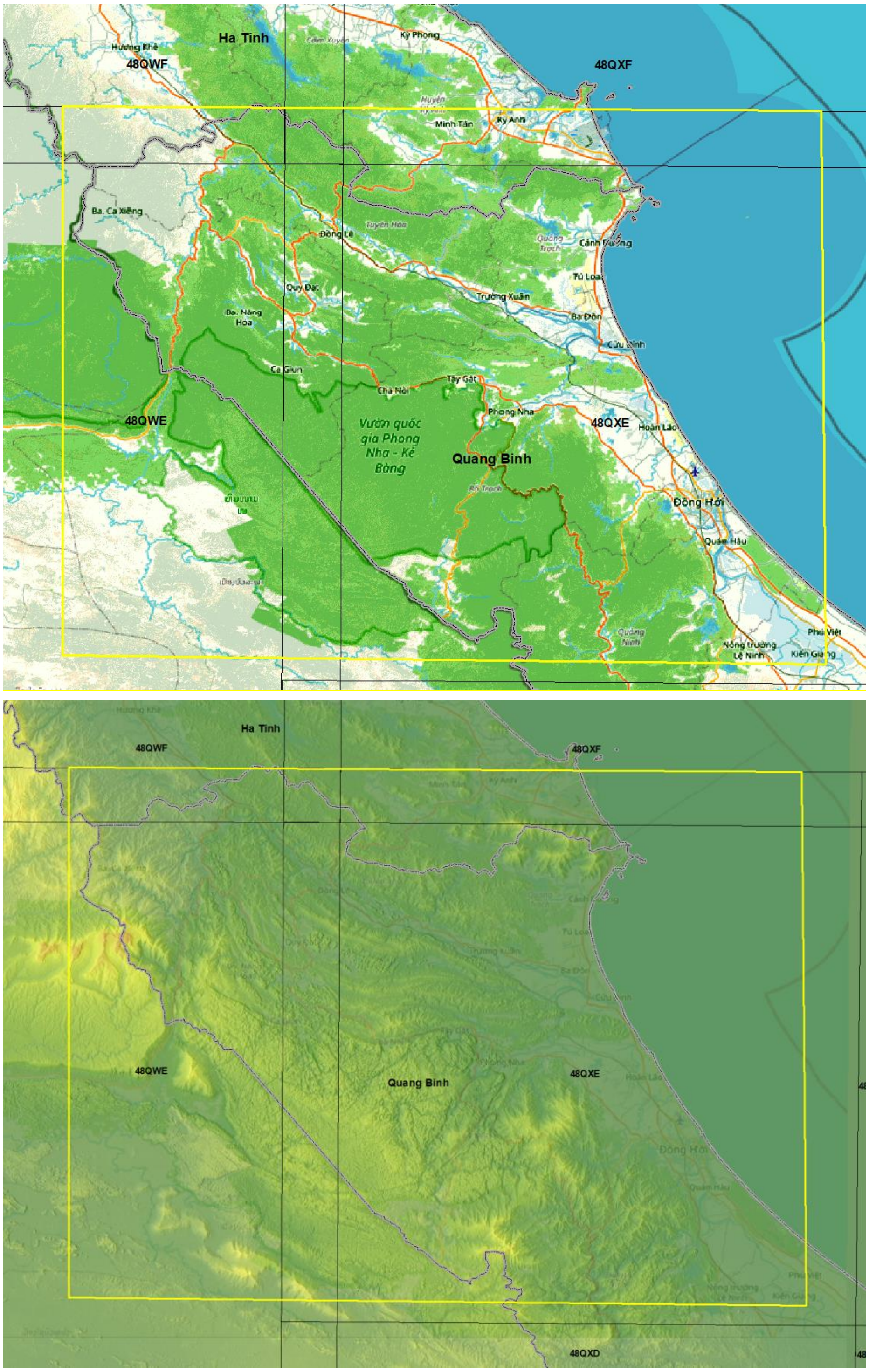

Figure 18: Test site (yellow) in North Central Region, Quảng Bình province. The test site covers Phong Nha-Kẻ Bàng national park as well as the lowland coastal areas. Above: OSM Basemap and JRC Tropical moist Forest layer Bellow: SRTM+ Topography

6.1.2 Germany (Federal State Hessen)

In order to test the EO services to be developed, a representative area in the north-east of Hessen is initially selected as a test site, which can be seen in Figure 19 and has an area of approximately 3000 km². The test site was chosen because it has a high proportion of state forest (Figure 19), which suggests a better data situation on the part of HessenForst. It mainly includes the five forest offices of Hessisch Lichtenau, Melsungen, Wehretal, Rotenburg and Bad Hersfeld.

Like most of Hessen, the area is located in the low mountain range, with the highest point being the "Hoher Meißner" with 754 m. The landscape is characterised by the two rivers Fulda and Werra and includes a wide range of landscape forms and elevation gradients. In addition to the topography, the tree species composition is also diverse and includes mainly beech, spruce and oak forests, which is a representative tree species selection for Hessen.

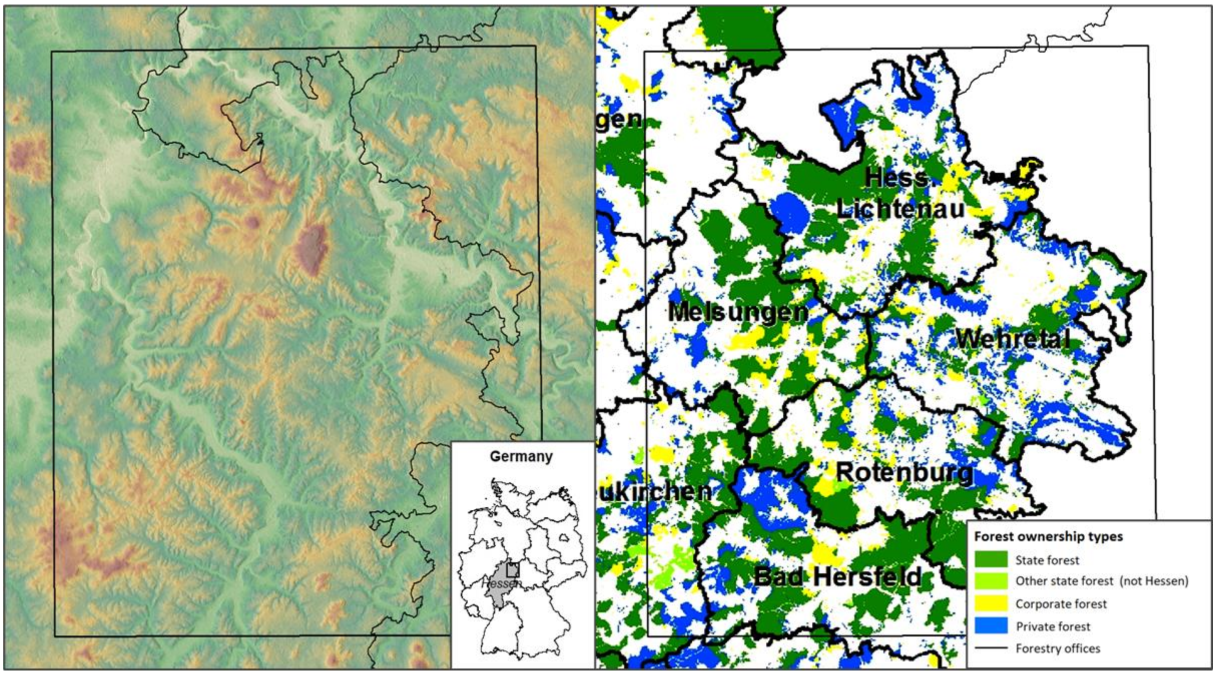

Figure 19: Test site for Hessen with its local terrain (left) and the forest ownership types [URL74]

6.1.3 Brazil

A good potential candidate area for the Brazilian test site could be located over a part of the Amazon rainforest straddling Brazil and Colombia (Figure 20). This sector has many natural parks and environmental protection zones. In addition, this is also an area where large indigenous reserves can be found [URL75] which is particularly interesting in our case if we consider assessing the impact of deforestation on these indigenous communities.

Our local pilot for the project would be the Brazilian CODS correspondent, as described above.

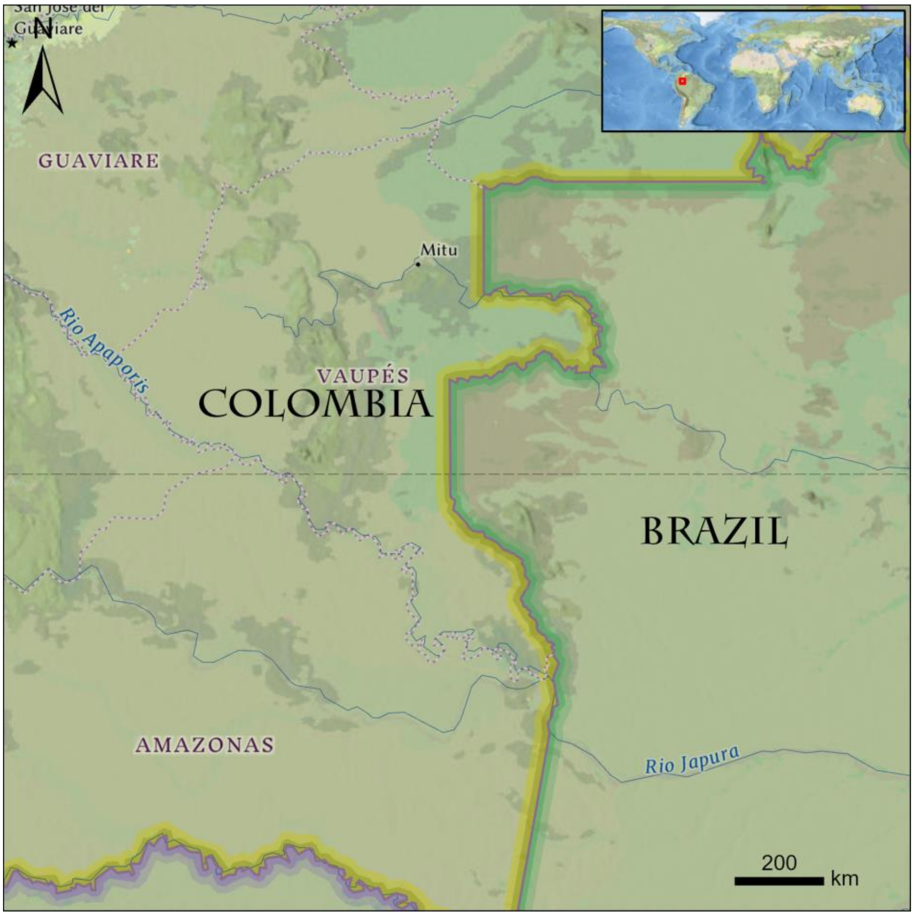

Figure 20: Location considered for the test site in the Amazon area

6.1.4 Colombia

Colombia has not carried out as thorough a reflection as in Vietnam, but however, the CODS considers that Colombia could host a test site, with the forest in the Pacific zone (Figure 21) or the Amazon region. The Amazon region is mentioned in the previous paragraph.

Figure 21: Location considered for the test site in Colombia

6.1.5 Ethiopia

Located within the Horn of Africa, Ethiopia has an area of 1.13 million km² [RD44] and covers altitudes between 110 m below sea level to over 4,600 m above sea level [RD42]. This wide altitude range leads to a diversity of climate, topography, soils and corresponding ecosystems, from tropical moist forests (high forest) in the highlands, over dry woodland areas to the desert-like landscapes in the Eastern part [RD42]. This diversity in ecosystems makes Ethiopia one of the top 25 biodiversity-rich countries in the world.

Four study areas with an overall size of about 30,000 km²were suggested to EFD which cover a wide range of different highland ecosystems. Study area 1 is located around Changni in the Amhara region, study area 2 is located around Korem and Dese partly in the Amhara and partly in the Tigray region. Study area 3 is located around Bonga covering the Kafa Biosphere Reserve and the 4th study area is located in Harenna and includes parts of the Bale Mountains National Park, both covering parts of Oromia region and Southern Nations, Nationalities, and People's Region (Table 28).

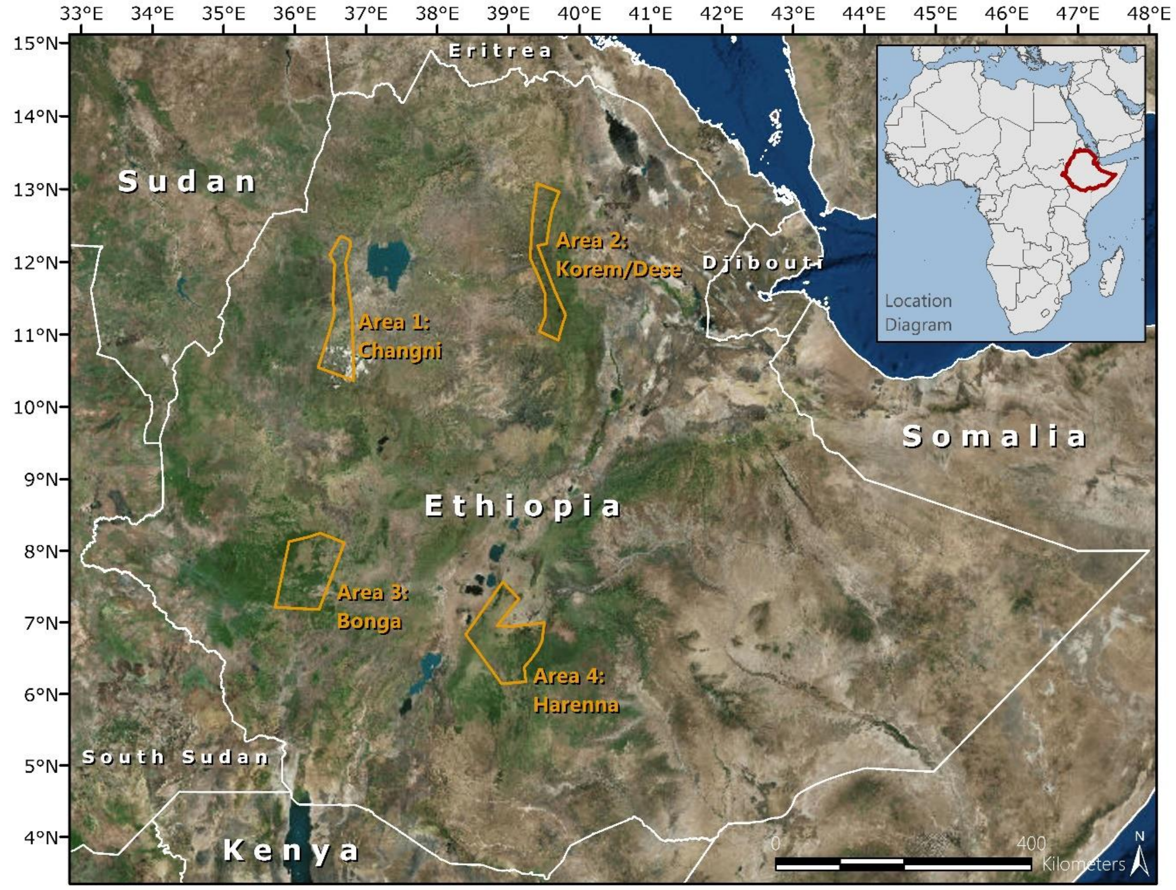

Figure 22: Suggested Test Sites for the product development

Table 28: List of study areas with their sizes, altitude ranges and location

Study area	Size [km²]	Altitude range [m asl]	Location
Changni	6,482	693 – 2,889	North-Western Highlands
Korem/Dese	5,529	1,374 – 3,947	North-Eastern Highlands
Bonga	8,533	1,186 – 3,031	Western Highlands
Harenna	9,693	1,327 – 3,849	Southern Highlands

6.2 National Demonstration

The purpose of the demonstrator is to test the feasibility, scalability, and robustness of the algorithms and strategies proposed within the Project. All relevant stakeholders will be brought together to work in joint in order to validate methodologies set up during the project. The large-scale demonstrator will analyse and showcase the algorithmic robustness, transferability of methods and usability of results and establish improvement actions where necessary. The demonstrator will monitor and record all stages of the production process. It is envisioned to establish key performance indicators to track the abovementioned aspects along the implementation process.

The demonstrator will be served on the Forestry Thematic Exploitation Platform (Forestry TEP, or F-TEP in short) following the FAIR principles. F-TEP is an online platform that enables users to efficiently access and process satellite data for forest monitoring purposes. It is operating on CloudFerro's CREODIAS1 infrastructure, one of the Copernicus Data Information and Access Services (DIAS) environments. The baseline processing environment available for all users consists of 8 virtual CPUs and 32 GB of RAM, along with temporary workspace storage of approximately 128 GB (SSD-type). Output product storage is not currently limited.

The Forestry TEP offers a wide range of readily available processing services and tools, and it enables users to create and share their own processing services, tools and products. The platform enables the scaling up of proof-of-concept work into a national demonstrator, it is possible to run large scale analysis for user defined areas of interest combining field datasets with satellite imagery available in the cloud storage. Based on the user engagement we identified several prospective thematic areas for the national demonstrators.

6.2.1 Vietnam

For the National Demonstration, the EO solutions will be sequentially scaled up to the Northern Central Region and to the whole country. Vietnam is covered by 79 Sentinel-2 tiles. The Northern Central Region is covered by 20 tiles (Figure 25). The test site is covered by two Sentinel-2 tiles. Vietnam is the easternmost nation on the Indochina Peninsula. The total surface area of the country is 32 931 400 hectares. Of this total surface area, 38.2% is forested area (i.e. 31.1% natural forest and 7.2% plantation forest), 19.4% bare land and 42.4% comprises other land [RD69].

Climate

Vietnam is situated in the tropical monsoon area of Southeast Asia and has a monsoon-influenced climate. Mean annual temperatures are around 24 to 25 °C in which the coldest month has a mean temperature of 17 to 20 °C (63 to 68 °F) and the hottest month has a mean temperature of 29 to 30 °C ° Average annual rainfall in coastal areas is approximately 2,000 to 2,900 mm The rainy season occurs in the last 6 months of the year with September and October having the highest rainfall (Figure 23).

Vegetation

UNESCO (1973) classified forest vegetation into 4 ecosystems [RD68]. In Vietnam, there are 4 layers: thick and thin ecosystem. Each ecosystem layer is divided into sub layer, which is further divided into ecosystem group and finally comes ecosystem itself. Individual ecosystem is divided into sub ecosystem.

A study on forest ecological stratification was carried out under the cooperation between FAO, UN-REDD Vietnam and Research Centre for Forest Ecology and Environment of Forest Science Institute of Vietnam to support development of Reference Emission Levels and implementation of MRV in REDD scheme in Vietnam. The results of forest stratification identified 2 ecological zones, 8 ecological regions and 47 ecological sub-regions (Figure 24). The ecological zones are North and South with the boundary is Hai Van pass and Bach Ma Mountain ranges. The 8 ecological regions include Northeast, Northwest, Northern Delta, North Central Coast, South Central Coast, Central Highland, Southeast and Southwest. Ecological sub-regions are basic area to define the formation and productivity of forest types. Four of the ecological sub-regions are islands area. The zonation overlaps considerably with the already established and widely used agro-ecological zoning.

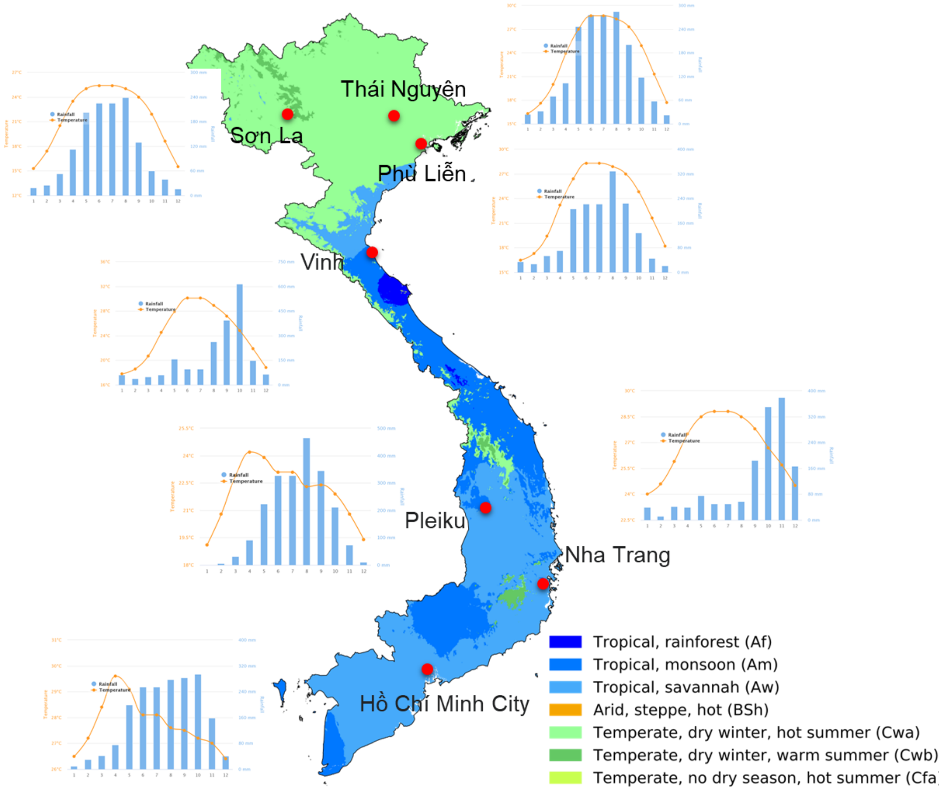

Figure 23: Köppen-Geiger climate classification map of Vietnam (1980-2016) [RD70]

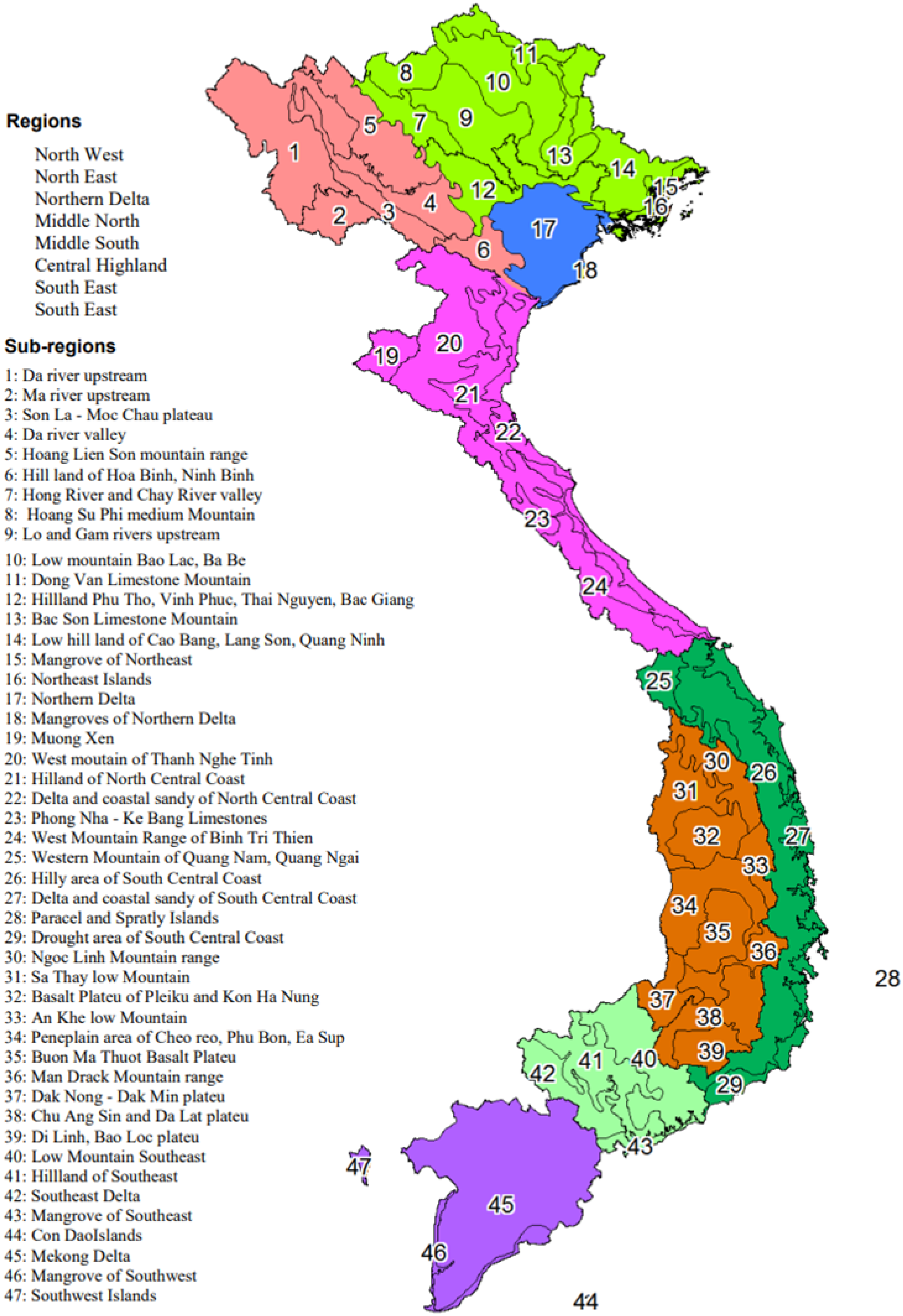

Figure 24: Vietnam forest eco-geographical zonation [RD68]

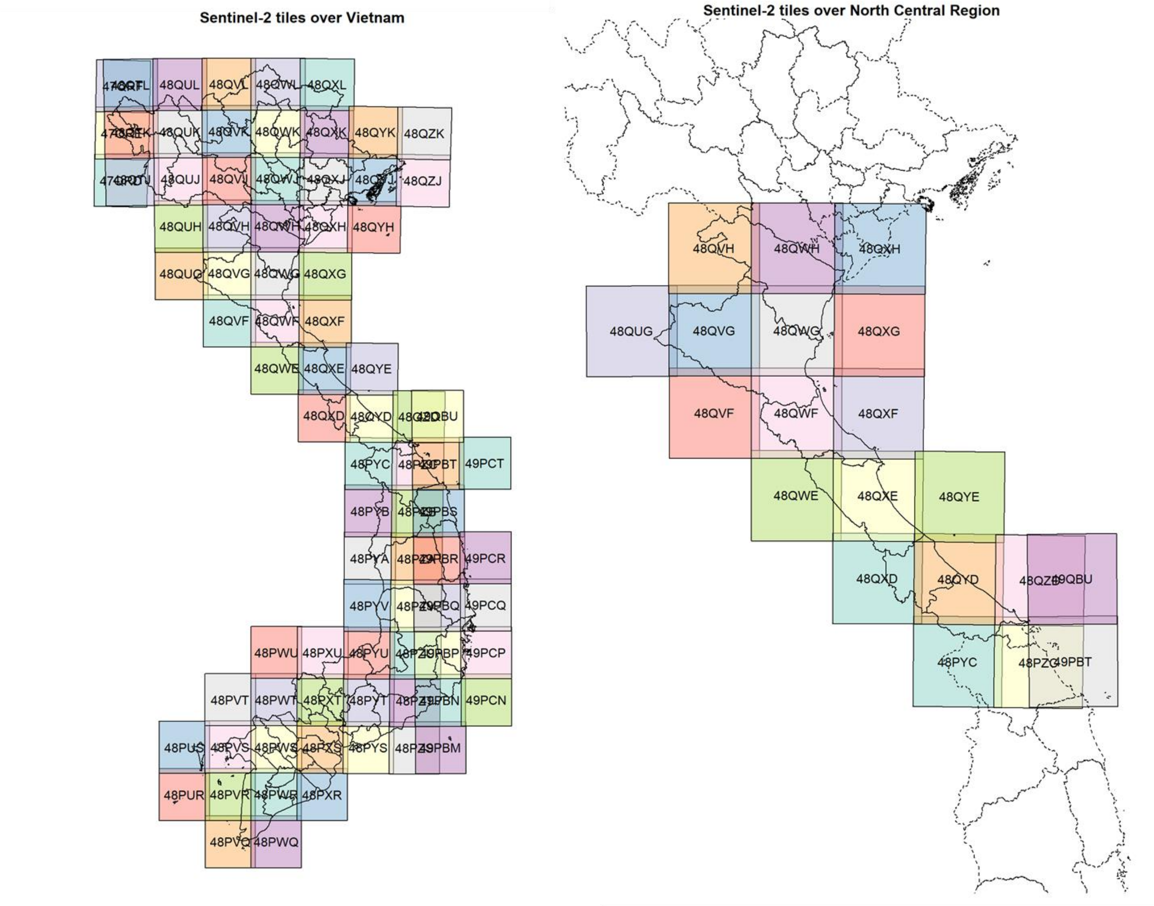

Figure 25: Sentinel-2 tiles over Vietnam (left) and over the Test Region (right)

<u>Data</u>

During the discussions with the user a list of national data was outlined (Table 29).

Table 29: National Geospatial Data for Vietnam

Geospatial layers	Coverage	Data format	Year; comments on the data (classes, minimum mapping unit; accuracy, …)
extend of forest and other woodland	National, regional, province	Both	1990 to 2021; classes, minimum mapping unit; accuracy based on map scales
forest characteristics such as age, species composition, canopy cover, etc.	Commune	Vector	2016; detail age and species composition are only for plantations. There is no information of canopy cover
plantations (rubber, palm oil, fruit trees, or other) as non-forest acc. to SDG	National, regional, province	Both	2016 to 2021, only for rubber
forests under protection, or under specific management type	National, regional, province	Both	2006 to 2021 for Special Use Forest and Protection Forest
forest expansion, deforestation, and net change, harvesting, reforestation, or natural rejuvenation	National, regional, province	Both	2000 to 2021

Geospatial layers	Coverage	Data format	Year; comments on the data (classes, minimum mapping unit; accuracy, ...)
plant functional types, forest types, forest tree species, biomes, ecogeo-graphical regions or other relevant ecological or ecomorphological classification	National, regional, province	Both	2016, but not including ecological or ecomorphological classification
Tracking forest fire or other destructive influences (storm, diseases)	National, regional, province	Both	2020, only tracking forest fire
forests under special international certification schemes	Forest owners	Both	
Forest on hills	Forest status types in commune to national levels		This data is online in http://www.kiemlam.org.vn/
Rocky/ limestone forests	Forest status types in commune to national levels		This data is online in http://www.kiemlam.org.vn/
Sandy forest	Forest status types in commune to national levels		This data is online in http://www.kiemlam.org.vn/
Mangrove and riparian forests	Forest status types in commune to national levels		This data is online in http://www.kiemlam.org.vn/

6.2.2 Germany (Federal State Hessen)

For the National Demonstration of the German Early Adopter, some of the EO solutions will be scaled up to the whole of Hessen. With its area of 21,115 km², Hessen has a suited size and diverse landscape for demonstrating the scalability and robustness of the EO solutions. At 42 %, Hessen has the highest forest cover of the German federal states [URL76]. This forest is 59% deciduous, with beech being the most common species (31%). The most widespread coniferous species is spruce with 22 %. The landscape of Hessen is relatively diverse with urban and rural regions, which is why forest density ranges from 15 to over 50 % depending on the district.

A total of 8 Sentinel-2 tiles covers Hessen completely as shown in Figure 26.

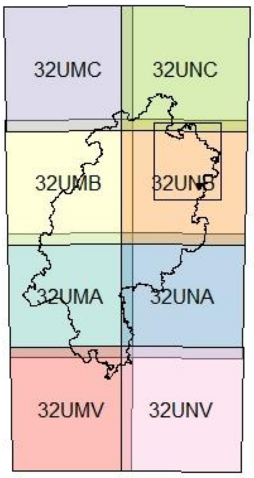

Figure 26: Sentinel-2 tiles over Hessen with the Test Region in the north-eastern part

6.2.3 Brazil

The Amazonian Forest is the largest rain forest in the world. We want to monitor all aspects of forest conservation, deforestation and all the changes that can be studied with Earth Observation data. A particular focus will be carried out for the monitoring of biodiversity. The next step will be to better know the local actors involved in the management of the territories, and who, if possible, will be able to ensure the link with the indigenous communities if they are not from there themselves. The support of the CODS in this research will be invaluable.

For the demonstrator it could be proposed to consider the Amazônia Legal area (also known as Brazil's Legal Amazon) [URL77] or at least a part of it for scaling-up some of the EO products. This area is particularly interesting given that it overlaps three different biomes (Amazon, Cerrado, and Pantanal) (Figure 27) and mostly covers the indigenous territory (Figure 28).

Figure 27: Location of the Amazonia Legal area and the Brazilian biomes

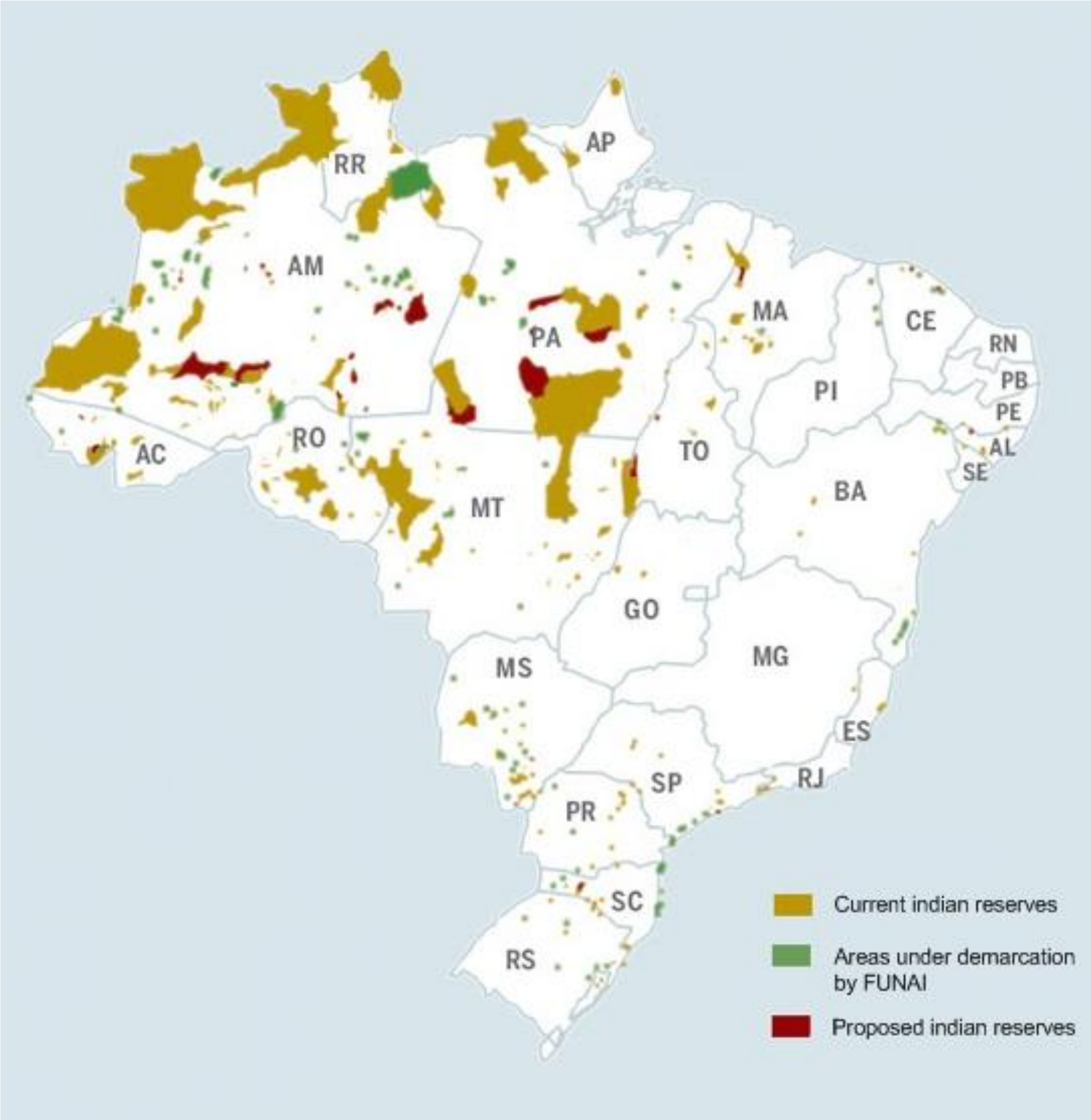

Figure 28: Current and proposed indigenous territories in Brazil [URL75]

6.2.4 Colombia

For the National Demonstrator the products will be scaled up to the level of entire coutry. Colombia is covered by 163 Sentinel-2 tiles (Figure 29). Less Sentinel-2 tiles are necessary to cover the whole Colombian territory in comparison with the Amazônia Legal area, but the exact extent of the demonstrator remains to be determined. We intend to study the same aspects as in the Amazonian part, such as biodiversity. It is also considered to carry out a demonstrator for some of the EO products that will be developed over the Colombian test site.

The forests are probably, because of its exposure to natural phenomena, subject to significant natural risks. It will therefore be necessary to follow it with this particular look. The “el nino” phenomenon also has a sometimes very strong impact on the entire western side of the continent. This must result in landslides, recent or old.

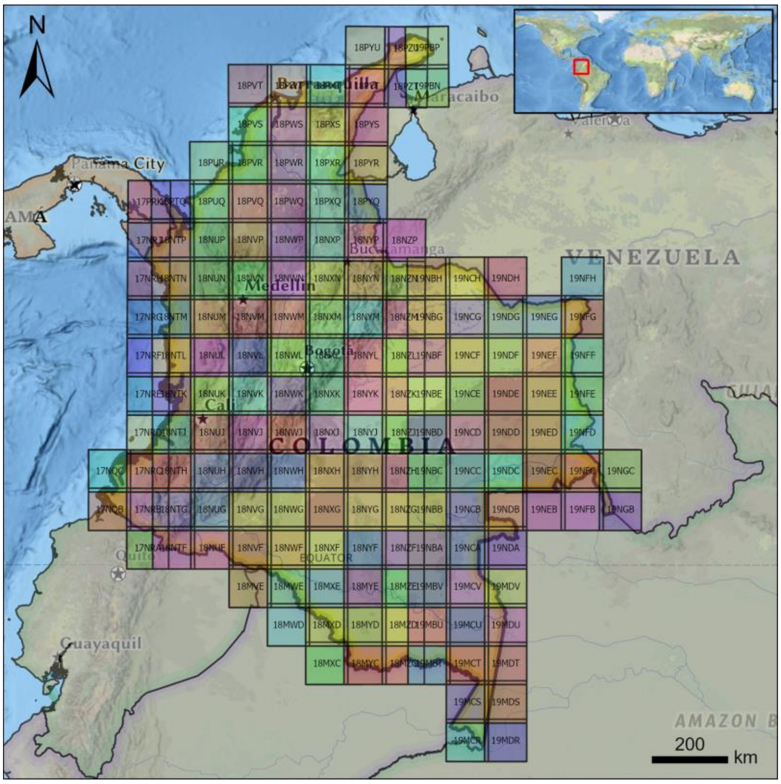

Figure 29: Sentinel-2 tiles over Colombia

6.2.5 Ethiopia

Since existing figures on national forest resources in Ethiopia vary greatly, there is a need to generate more accurate and precise forest inventory data at low level of uncertainty. The Global Forest Watch (GFW) map products from the University of Maryland could be the basis to develop forest area statistics at national level. However, these forest map products require specific calibration of the tree cover percentage [RD71]. Based on the high-resolution forest benchmark maps from the four test sites in Ethiopia, an optimal forest-type dependent calibrated thresholds of tree cover density for the GFW dataset can be assessed, in order to generate a calibrated forest map for Ethiopia. To consider for the different ecosystems in Ethiopia, the dataset of the "Potential Vegetation of Ethiopia" [RD72], showing potential distribution of the 15 natural vegetation types, can be used to find these forest-type dependent thresholds. The potential vegetation map can be aggregated to the main three potential forest types in Ethiopia, 1) Moist/transitional evergreen forest, 2) Dry evergreen forest and 3) Woodland. In the four test sites, a detailed comparison between the high-resolution forest classification and the GFW data will be performed. By applying 1%-wise thresholds of tree cover percentage from 1 to 100, 100 GFW-based forest classifications will be created first. An accuracy assessment between each classification and the high-resolution map per forest-type based on random points in the test sites will be conducted. For the final selection of the optimal tree cover percentage for classifying forest in each forest type, the fit between the classifications is considered as well as the ratio of commission and omission errors. For each forest type, the tree cover percentage is then chosen that showed an overall fit of at least 70% with the lowest difference between commission and omission errors (to avoid major over- or underestimations of forest). The GFW data set from Ethiopia are then clipped to the three forest types indicated by the potential vegetation map and then ecosystem-wise classified by the use of the three different tree cover percentage thresholds. The result is a calibrated GFW forest classification for Ethiopia. Since the GFW tree cover dataset bases on the reference year 2000, the final calibrated map is further corrected for forest gain (until 2012) and forest loss (until 2017) that are also part of the GFW data. Through this approach, a scale-up to the whole country can be achieved.

6.3 Use Case

Use cases address specific applications in the Early Adopters work environment. Their aim is to make existing process chains more effective and to implement new solutions. In this project, the reporting chains of the SDGs are supported, and additional metrics are implemented to increase the granularity of the results. At the present state it is still difficult to describe the use cases with full precision. We aim to define and specify specific Use Cases and the main details within the following months, endorsed by further discussions with the users. In Table 30 we describe the main groups of adopters and Table 31 outlines the scope of the future use cases.

Table 30: Main actors to use the EO solution portfolio

Actors	Description
Government Officials	Government officials working in the forest sector utilize the application to monitor and manage their country's forests, track progress towards sustainable development goals, evaluate policies and interventions, and make informed decisions about forest conservation and management strategies.
Forest Managers	Forest managers, including forest rangers, conservationists, and forestry experts can rely on the application to monitor changes in forest cover, detect forest disturbances, plan reforestation efforts, and implement sustainable forest management practices.
Policymakers	Policymakers at the national, regional, and local levels can use the EO Solutions to evaluate the effectiveness of existing policies, develop evidence-based policies and interventions, and support decision-making related to forest conservation and management.
NGOs	Non-governmental organisations (NGOs) and environmental organisations working in the forest sector can use the EO solutions to conduct research, advocate for sustainable forest management, and engage in awareness campaigns.
Local Communities	Local communities living in or around forests are important stakeholders in forest sustainability. They may use information about the state of their local forests, participate in decision-making processes, and advocate for sustainable forest management practices.

Table 31: Scenario Areas

Scenario	Description
Tracking progress towards SDG	Government officials in a developing country are tasked with monitoring and managing their country's vast forest resources to ensure sustainable development and sustainable forest management. They use the provided, the satellite imagery analysis application, to track progress towards their country's forest sustainability goals.
Forest Cover Monitoring	Using Forest Mask, government officials can monitor changes in forest cover in real-time, identifying areas of deforestation or reforestation. They can track the extent and rate of forest loss or gain, assess the impact on biodiversity, and identify hotspots that require immediate attention.
Policy Evaluation	Government officials can analyze historical data and trends in forest cover changes to evaluate the effectiveness of existing policies and interventions. They can identify areas where policies are successful and areas where further action is needed to promote sustainable forest management and achieve development goals.
Reporting and Stakeholder Engagement	Reporting and visualization features allow government officials to generate comprehensive reports and visualizations to communicate the status of forests to stakeholders, including policymakers, NGOs, and local communities. These reports help in evidence-based advocacy, stakeholder engagement, and informed decision-making.

Scenario	Description
Sustainable Forest Management Planning	Data and analysis support government officials in developing and implementing sustainable forest management plans. They can use the application's insights to prioritize areas for reforestation, plan conservation activities, and allocate resources efficiently to ensure sustainable forest management practices.

6.3.1 Vietnam

The process of user engagement is ongoing. A bilateral meeting is scheduled to define concrete use cases for the solutions based on the user needs. Below is a short outline of the primary actor and the scope of the use cases.

Primary Actors: Government officials, Forest Managers (FIPI, MARD staff members)

Scope: Forest Cover Monitoring, Evaluation of National Policies, Reporting on SDG

6.3.2 Germany (Federal State Hessen)

Currently, no clearly defined use cases can be identified for Hessen. On the one hand, a more in-depth discussion with the EA is necessary in order to integrate the EO solutions as efficiently as possible into their SDG strategy. On the other hand, the EO solutions themselves still need to be technically defined more clearly, which depends, on the input of the EA and on the algorithm trade-off. Findings and experiences from the test site will flow into the development of suited showcases.

6.3.3 Brazil

The two projects, Amazon rainforest in Brazil and Colombia, are linked. We wish to rely on these two projects, to have a broad view of the issue of the SDGs applied to Latin America:

- calculation of SDGs
- dissemination of information to local partners
- up to national level
- exchanges and improvement of methods and circulation of information

6.3.4 Colombia

The reflection has not yet begun on this point. The project can be an opportunity to carry out studies to go further, nationally and internationally.

The role that we wish to entrust to the CODS corresponds to their development policy and should therefore be a lever for the dissemination of our results at all levels.

We can imagine a dissemination of the results of the project, which would go beyond Colombia and Brazil to be on the scale of the continent.

6.3.5 Ethiopia

A potential national demonstration of some products will be discussed with the Early Adopter after an initial demonstration of the products at study area scale.

7 Executive Summary

The Requirement Baseline Document serves as the basis for all activities carried out during the project.

Chapter 2 provides a review and analysis of the underlying SDG policy framework addressed by the project including the United Nations (UN) Sustainable Development Goals (SDGs) policy framework, the indicator set related to Goal 15 Life on Land, specifically Targets 15.1.1 and 15.2.1, and key national and supranational SDGs policy frameworks for each participating EA. A thorough review of the most relevant strategy and guideline papers was also performed.

In Chapter 3, a comprehensive characterization of the target SDG User Group and their SDG needs and challenges is conducted. The EAs have invested in forest management to various degree. Most countries have established forest sustainability goals and developed indicators to track the progress towards SDG realization. The indicator sets are largely modelled after the UN indicator set though more concrete and detailed measurements are also adopted. Some EAs are more advanced than others in implementing efficient SDG monitoring systems. Here, continuous and homogeneous data acquisition, and subsequent data analysis is often a challenge. Particularly for monitoring large-scale and difficult-to-access forests, EO approaches are a valuable tool. The forest dynamics of the EA countries differ as well. For example, the West African EA countries are experiencing a sharp decline in forest cover, whereas forest areas in Vietnam are increasing. Especially in recent years, when all EAs are feeling the effects of climate change on their forests, insightful monitoring of forests is crucial.

Chapter 4 assesses how EO could help address the needs described in the previous chapter. A comprehensive overview of best practices on EO-based forest monitoring with regard to SDG 15 is provided. The chapter shows why data-driven solutions are essential for Forest SDG monitoring and how cloud-based analytics platforms and AI can help to analyse big data.

Chapter 5 curates a collection and analysis of the SDG requirements that the project aimed to address. It reviewed the primary requirements in terms of SDG monitoring and reporting needs, presented a list of technical requirements for the EO solutions, and outlined the identified user requirements as well as the product validation requirements.

Chapter 6 presents the foreseen test sites and national demonstrations proposed for testing, development and up-scaled application of the EO solutions. Potential use cases in the EA countries for the SDG reporting are outlined.

Based on the research and the conversation with the EAs, a set of criteria for the development of the new indicators was established. The indicators should be selected based on five criteria: (a) **relevance** to monitoring the achievement of the SDGs; (b) **statistical adequacy**; (c) **timeliness**; (d) **data quality** and (e) **coverage**. Furthermore, the indicators for tracking progress towards sustainable development are intended to be used by policy makers. Therefore, they need to be **simple** and **understandable**. The cause-and-effect dynamic must be comprehensible. The indicators for tracking progress towards sustainable development must be **reproducible**. They need to have a clear and unambiguous methodology without any statistical randomness. The indicators must be **transferable** across ecosystems and geographical regions to enable global tracking of progress towards sustainable forest management. The indicators must be temporally and spatially **robust**, on order to have comparable ranges in order to allow tracking of **specific** aspect of sustainable development. It must be clear which aspect of sustainable development (environmental, social, economic) the indicator is being tracked. If an indicator is tracking the progress towards more than one aspect of sustainable development, it should acknowledge the feedback effect between the three aspects. The efforts made within the ongoing project will take the chance to address these aspects with its solution developments.

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