

# The role of Earth Observation and AI in forest monitoring

## Way forward for climate mitigation and adaptation

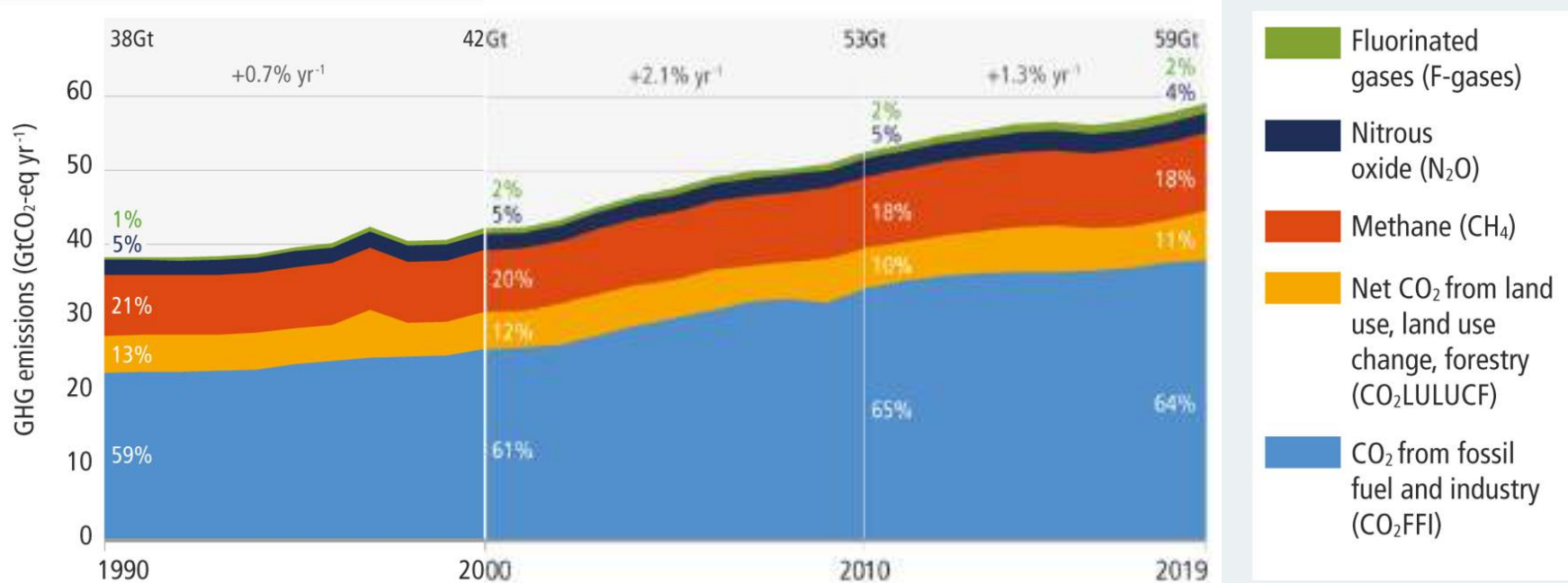
**Dr. Inge JONCKHEERE**  
FAO Forestry Division  
Forest & Climate Group



Project Meeting, Windhoek, Namibia  
20 Sept 2023



We are not on track to limit warming to 1.5 °C.



# Background



Environmental change: climate crisis is here and now (IPCC, 2022): monitoring & forecasting forest and land (cover/use) has become crucial more than ever to

**Global scale:** variety of data/data sources

**National scale:** global data used nationally or national data for different (international) reporting frameworks

FAO/SilvaCarbon in collaboration with ESA/NASA, academia and other partners have developed tools to assist countries in measurement, reporting, and verification (MRV) through GFOI

It all starts with...

...data!

to predict, mitigate and respond to forest disturbances,  
and enable more effective and sustainable forest  
management as well as adaptive measures.

# National Forest Monitoring, MRV and Platforms

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**VISION:** Innovative, accurate, and transparent forest monitoring can unlock the potential of forests for climate action and many of the other benefits that forests provide.

**HOW WE WORK:** We build platforms and capacity for the collection of data, for the creation of critical forest information by those who manage forests and are at the front line in mitigating and adapting to climate change.



# 50 years of support and expertise

In ***National Forest Monitoring***



# Open Foris



Developed in collaboration with over 70 countries and partners

FAO's first open-source initiative launched in 2011

Now open-sourced DPGs mainstreamed across FAO

35,000

Users

of Open Foris

>195

Countries

Used Open Foris

**FAO membership** to the Digital Public Goods Alliance

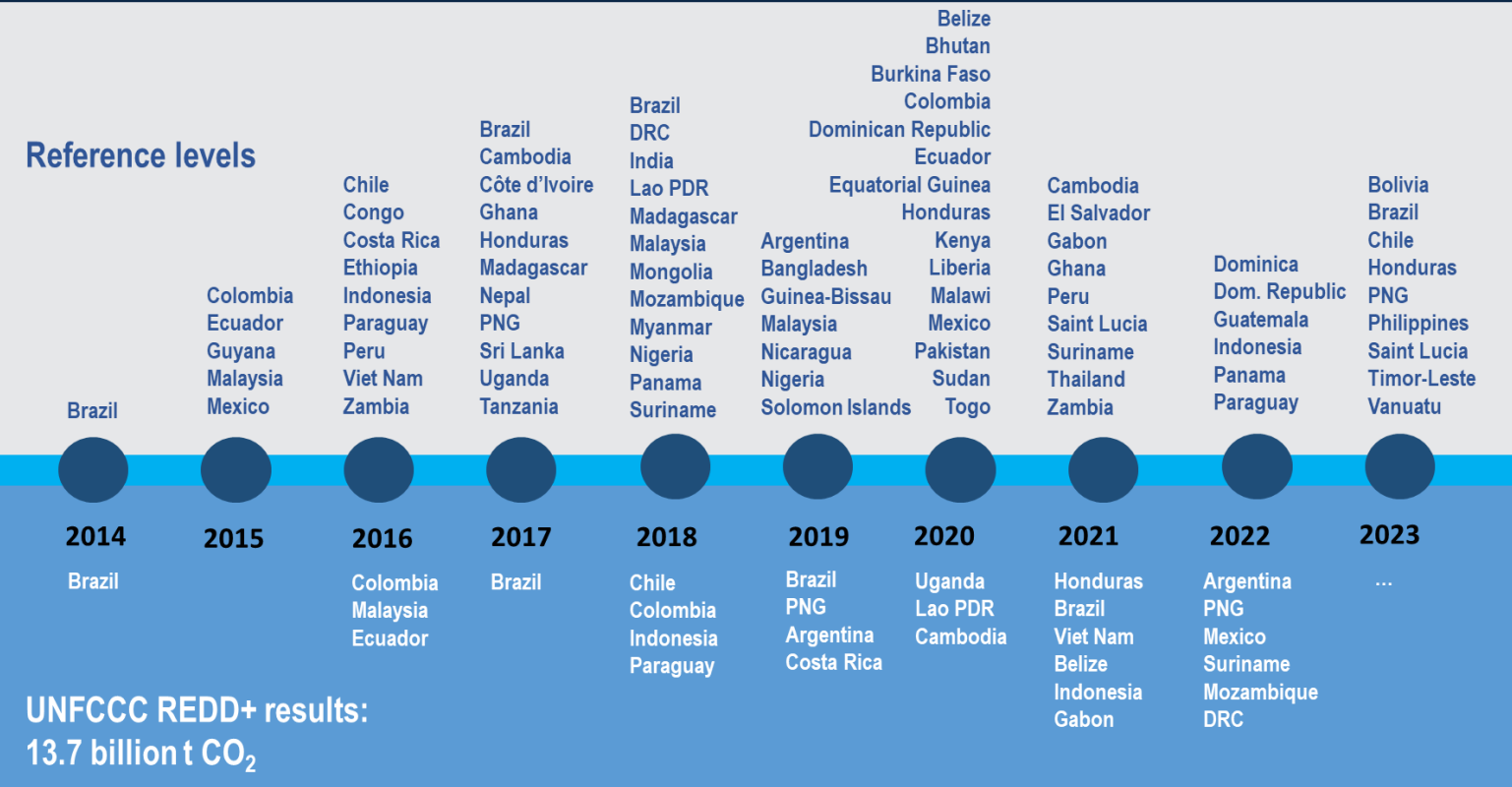
**OpEd** - How Digital Innovation Has Accelerated Monitoring of the World's Forests

**COFO Information Note** on Digital innovation for data collection and dissemination on forest resources, their management and uses

# 10 years work on MRV - reporting (UNFCCC, FCPF, GCF etc.)

90% of countries used *OpenForis*

70% received Technical Assistance from NFM



87 FRL submissions

28 REDD+ result submissions

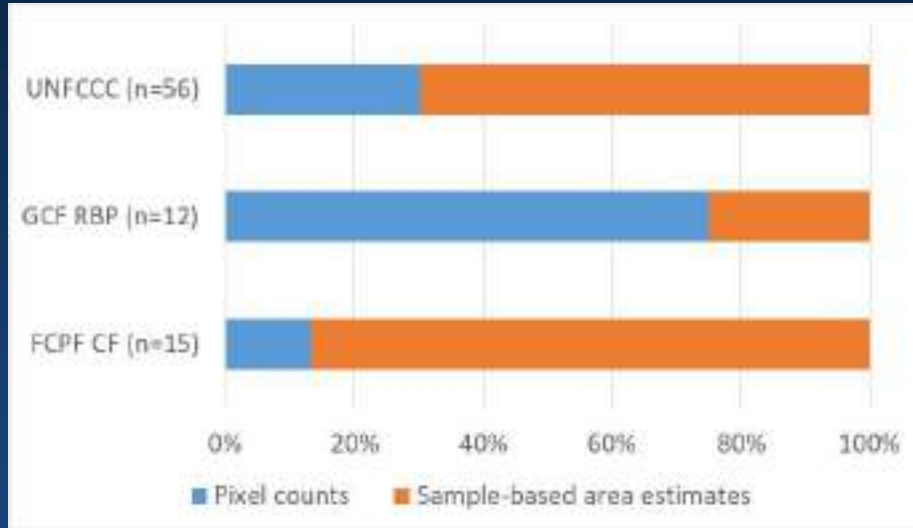
13.7 billion t CO<sub>2</sub> reductions / enhancements

UNFCCC REDD+ results:  
13.7 billion t CO<sub>2</sub>

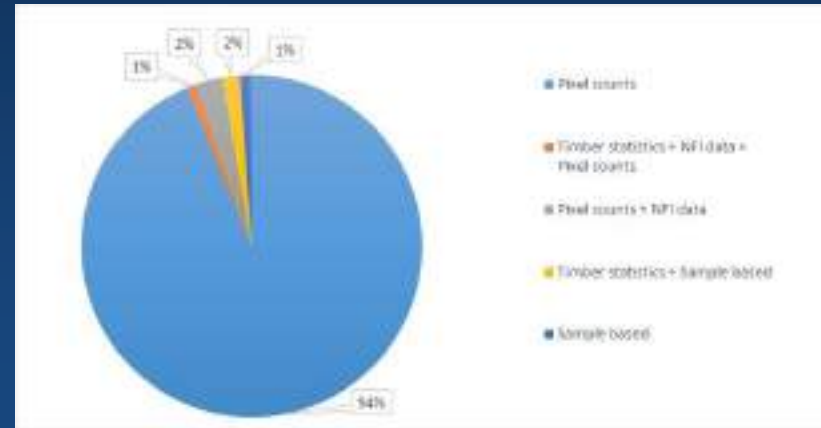


# Methods Activity Data

## Reference levels

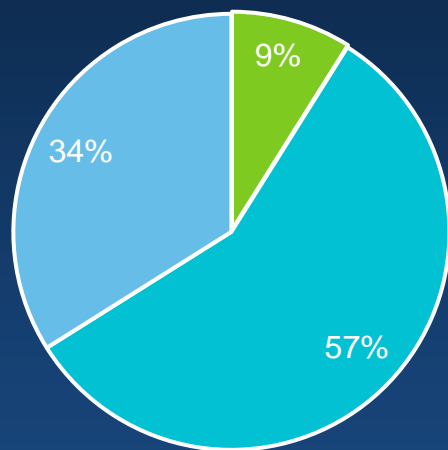


## Results reported UNFCCC



# Methods Emission Factors

countries submitting reference level to UNFCCC:



■ No NFI

■ NFI with one cycle

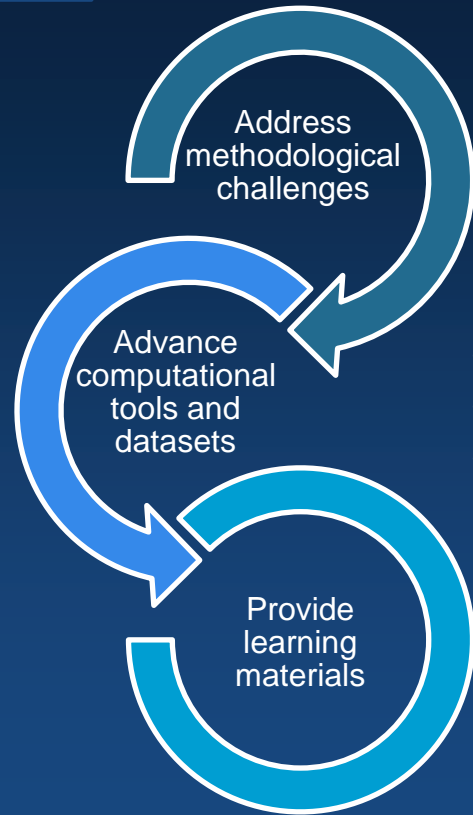
■ NFI with more than one cycle

Most countries have NFI or inventory data suitable for deforestation EF

Challenges:

- NFI data for degradation EF
- NFI data for A/R
- Take advantage of multiple cycles

# How to progress towards high-integrity data



- Sample-based area estimation
- Forest degradation
- QM in emissions inventories

- SEPAL
- Forest regrowth rates
- Peatland decomposition rates

- E-learning
- GFOI Family of Resources

# The landscape of carbon finance opportunities

Results-based  
payments



Compliance  
markets



Voluntary  
carbon markets



# FAO Applications and Resources

A short overview

# Open Foris initiative

[www.openforis.org](http://www.openforis.org)

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Free and open source tools and methods for data collection, analysis and reporting



## Arena

Online platform for survey design, data management, utilization and processing



## Collect

Easy and flexible survey design and data management



## Collect Mobile

Intuitive data collection and validation in the field



## Calc

Efficient and collaborative data analysis and results dissemination



## Collect Earth

Easy and flexible survey design and data management



## Collect Earth Online

Online Land Monitoring tool for crowd-sourcing of augmented visually interpreted data



## Earth Map

The power of Google Earth Engine without coding. A user friendly tool for complex land monitoring



## SEPAL

System for earth observation, data access, processing, analysis for land monitoring

## Key principles

- **FAO-led initiative**
- **Free and open source:** approx. 30,000 downloads since 2016; source codes are available in [GitHub](#).
- **Software development:** new and improved versions of the tools are released periodically.
- **Collaboration:** FAO [Hand-in-Hand](#) Initiative; private and public partners (e.g. Google, NASA-Servir); academic institutions; projects.
- **Country testing:** OF tools have been used in more than 130 countries.
- **Capacity building:** training sessions on all OF tools in all regions of the world.
- **Implementation:** more than 44 countries have integrated OF tools in their forest monitoring systems.

## Data vs information

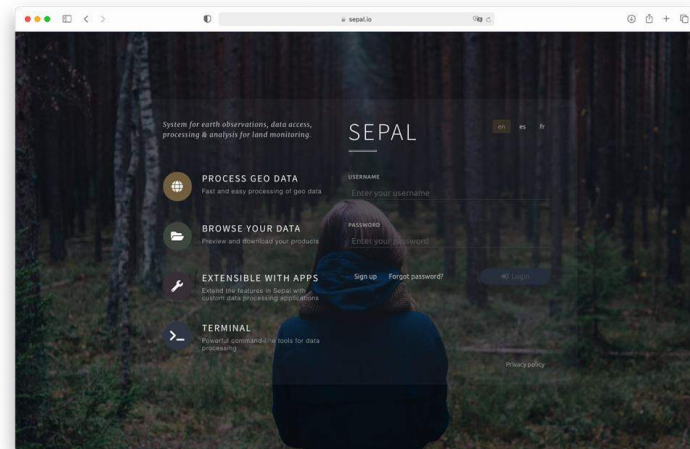
- AI: Extraction of useful relationships: use of machine learning
- Combining satellite/ Lidar data (remote sensing observations) with in-situ information
- Predictive AI: probability of extreme events or hazards e.g. pest or fire outbreaks



# SEPAL: Earth Observation and cloud computing



- SEPAL is a cloud based platform for accessing, processing and analysing geospatial data for land monitoring
- SEPAL is free and open: anyone can register for access to its features: <https://sepal.io>
- All you need is an Internet connection to access the SEPAL website



esa

ETH zürich



KFW

SilvaCarbon



Google



# SEPAL

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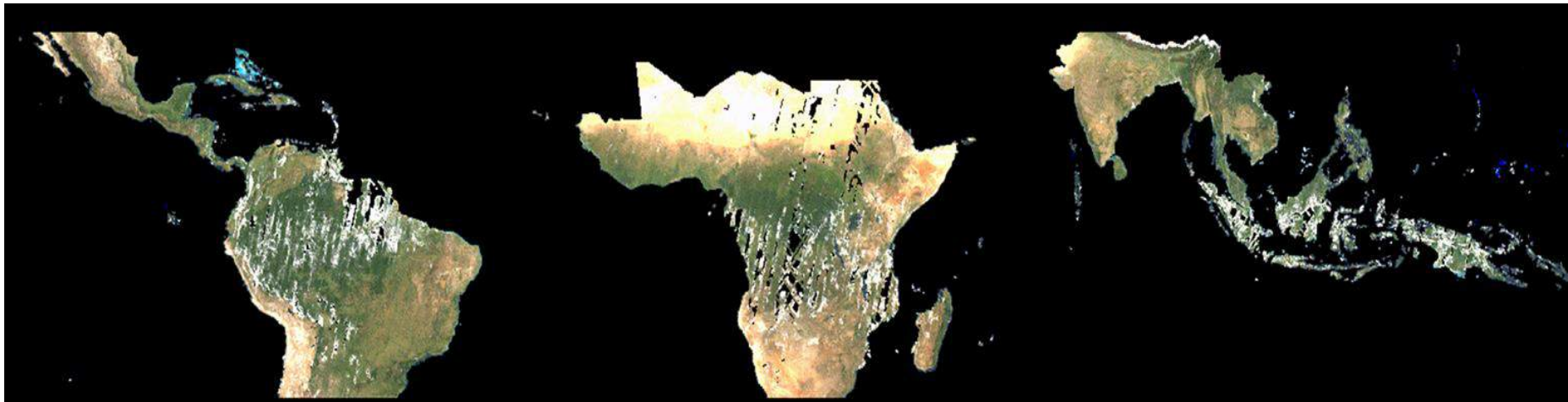
*System for earth observations, data access, processing & analysis for land monitoring.*

Signup

Launch



## Planet data



Pan-tropical, high-resolution data offer amazing opportunities

(Slides courtesy of R. D'Annunzio)

- Expand use and application of NICFI-Planet data
- Develop the SEPAL platform to be even easier to use for critical forest and land monitoring needs and high-integrity forest data
- Apply innovative capacity development methods to reach all 64 countries included in the NICFI-Planet data program
- Develop user-friendly applications of the NICFI-planet data
- Country level engagement
- Multi-donor project; additional contributions welcomed



SEPAL



**>10,000**

Active users



**>300**

Organizations



**>180**

Countries

# SEPAL <https://sepal.io>

## SEPAL provides many capabilities



Search and process  
satellites imagery



Access super computers

Mobile and tablet  
compatibility

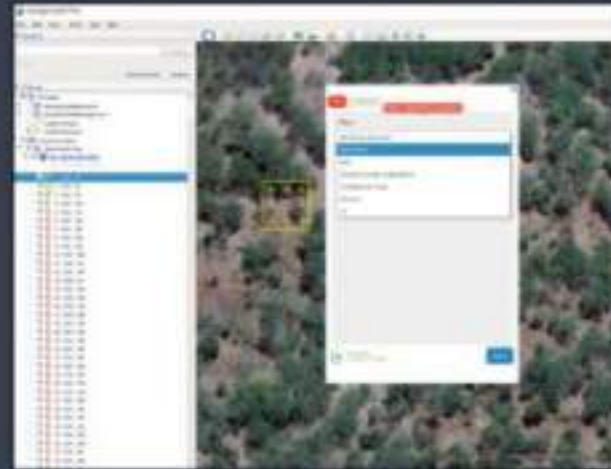
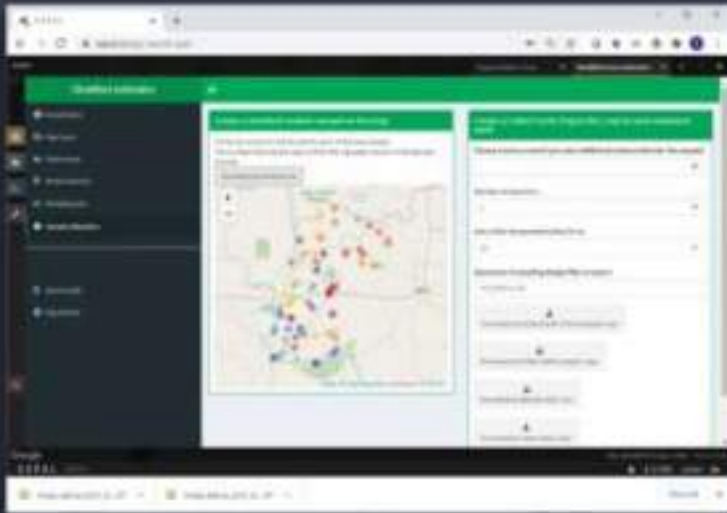


Store and access data



Analyze data using predefined  
processing chains

# SEPAL -module example



module name :  
Stratified estimator design

Stratified Random Sampling for Accuracy Assessment

# SEPAL

## Link to Collect Earth and Collect Earth Online

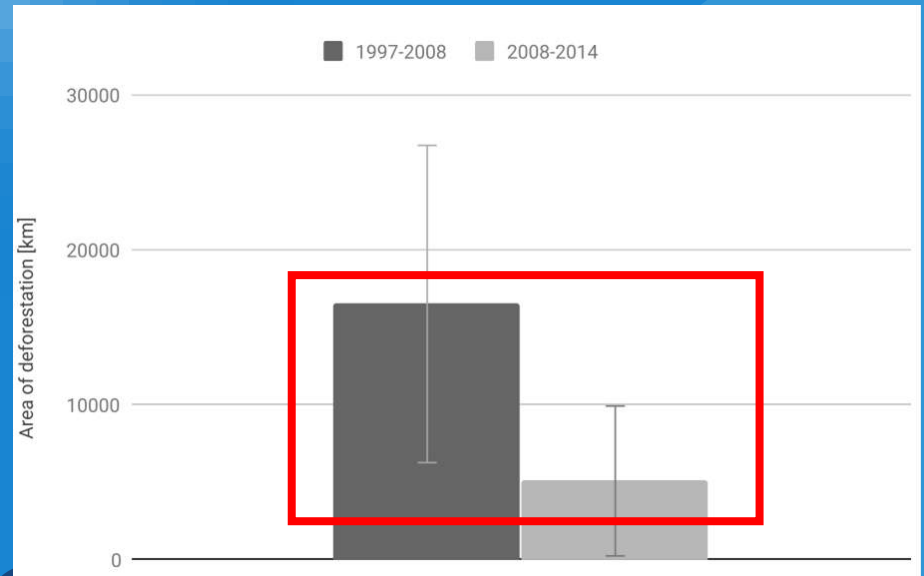
Collect Earth can be used with  
Sepal to produce training data.

Follow our tutorials for more  
information



# New module: eSBAE (Sample Based Area Estimation)

- Support countries in accessing *Carbon Finance*
- *Reliable* estimates of Forest Change (High-integrity)
- *Consistency* over time
- Address *Uncertainty*
- Being *practical*
- *Manage* expectations



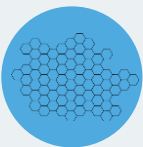
source: Olofsson et al., 2020



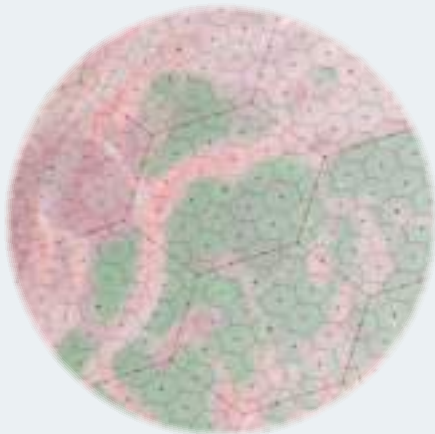
# Overview - Ensemble



Time-Series Extraction



Dense systematic sampling grid: 500m to a few kms



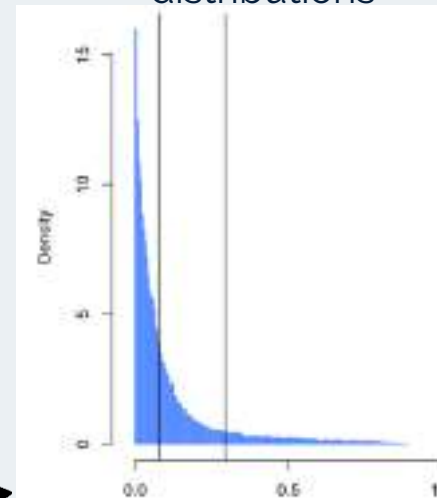
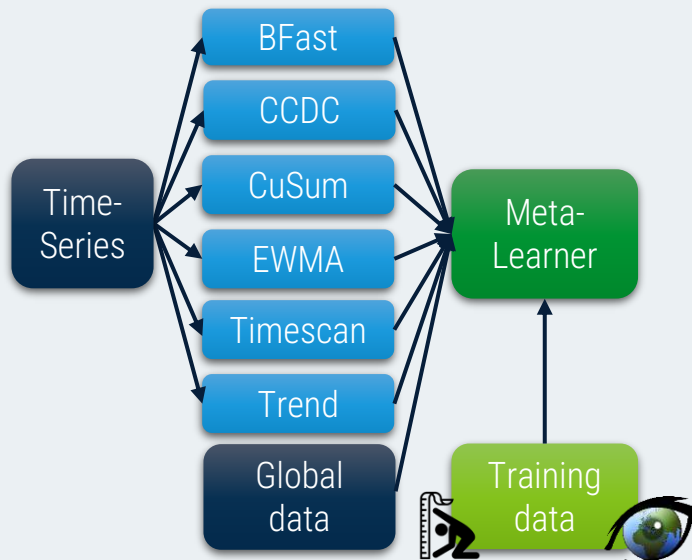
Probability of potential change as proxy for actual change



**AI**  
Ensemble of Change



Dalenius type of stratification: optimized for skewed stat. distributions



Potential Change Probability

# On SEPAL



- eSBAE notebook series
- Streamlined & automated process
- Based on Google Earth Engine and various geo-spatial python libraries
- Use of AI for the calculations

~300k

Points

2 days

Time-series & Data  
Augmentation

~10 \$

Processing cost



# Collect Earth

Visual interpretation tool for land use/cover classification and change detection with access to high and very high resolution satellite imagery

# Augmented Visual Interpretation

Data Collection tool integrated in Google Earth.

Free access to Very High Resolution imagery.

Multitemporal imagery thanks to Google Earth, Bing Maps and High Resolution

The image displays the Google Earth Pro interface with a data collection tool overlaid on a satellite view of a mountainous island. The tool includes a list of data points on the left and a detailed analysis panel on the right.

**Data Collection List:**

ID#	Value
1 - ID#	: 334
2 - ID#	: 316
3 - ID#	: 276
4 - ID#	: 242
5 - ID#	: 154
6 - ID#	: 297
7 - ID#	: 393
8 - ID#	: 390
9 - ID#	: 409
10 - ID#	: 197
11 - ID#	: 180
12 - ID#	: 346
13 - ID#	: 194
14 - ID#	: 212
15 - ID#	: 416
16 - ID#	: 219
17 - ID#	: 292
18 - ID#	: 98
19 - ID#	: 367
20 - ID#	: 60
21 - ID#	: 426
22 - ID#	: 319
23 - ID#	: 251
24 - ID#	: 308
25 - ID#	: 425
26 - ID#	: 175
27 - ID#	: 275
28 - ID#	: 411
29 - ID#	: 312

**Vegetation Analysis Panel:**

Latest vhr image available: 2016

Vegetation type and cover:

Vegetation type	Vegetation cover
Tree	40-49%
Shrub	0%
Palm	0%
Bamboo	0%
Crop	0%

Tree Count: 17

Shrub Count: 0

Mapbox selected

Google Earth Pro interface details: Imagery Date: 3/6/2016, 27 P 221087.82 m E 1669439.55 m N.



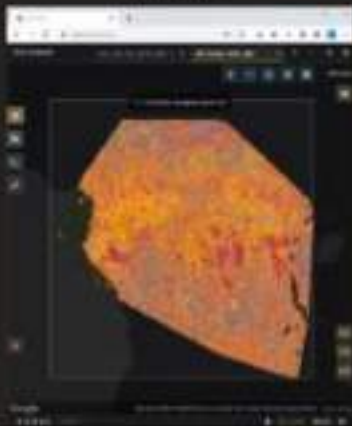
# Collect Earth Online

Visual interpretation tool for land use/cover classification and change detection with access to high and very high resolution satellite imagery

Used globally

## Fusion Optical and radar data

ALOS



LANDSAT 8



ALOS + LANDSAT 8



Carrasco, L., O'Neil, A.W., Morton, R.D., Rowland, C.S. Evaluating Combinations of Temporally Aggregated Sentinel-1, Sentinel-2 and Landsat 8 for Land Cover Mapping with Google Earth Engine. *Remote Sens.* 2019, 11, 208. <https://www.mdpi.com/2072-4292/11/2/288>

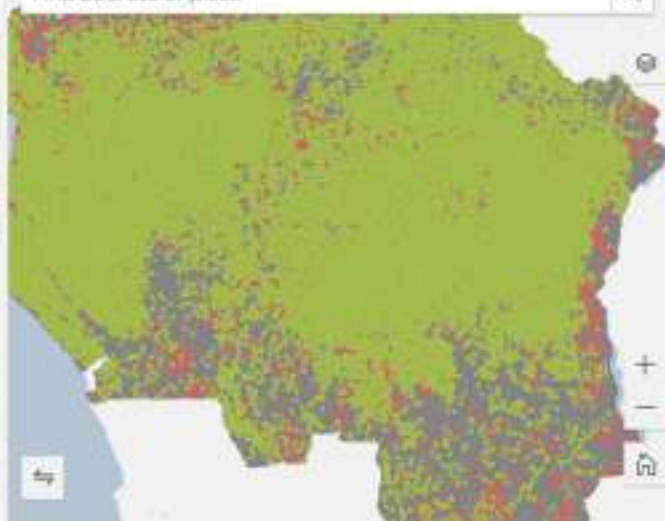
Hirschmugl, M., Sobie, C., Deutscher, J. and Schardt, M., 2018. Combined use of optical and synthetic aperture radar data for REDD+ applications in Malawi. *Land*, 7(4), p.116.

Josh, N., Baumans, M., Ehammer, A., Fensholt, R., Grogan, K., Hostert, P., Jensen, M.R., Kuersteiner, T., Meyfroid, P., Mitchard, E.T.A., Reiche, J., Ryan, C.M., Wasse, B. A Review of the Application of Optical and Radar Remote Sensing Data Fusion to Land Use Mapping and Monitoring. *Remote Sens.* 2016, 8, 70.

Chang, Chia-Hao & Hsieh, Yi-Ta & Wu, Shou-Tsang & Chen, Chiau-Tzuin & Chen, Jan-Chang. (2015). Applying Image Fusion to Integrate Radar Images and SPOT Multi-spectral Satellite Images for Forest Type Classification. *Taiwan Journal of Forest Science*, 30, 201-209.

Total points: 359,978

Find address or place



## Validation Plot: 1

ISO	COG
LON	15.667202
LAT	0.914955
CUSUM Code	303
CUSUM date	2019.5269673

PART 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100, 101, 102, 103, 104, 105, 106, 107, 108, 109, 110, 111, 112, 113, 114, 115, 116, 117, 118, 119, 120, 121, 122, 123, 124, 125, 126, 127, 128, 129, 130, 131, 132, 133, 134, 135, 136, 137, 138, 139, 140, 141, 142, 143, 144, 145, 146, 147, 148, 149, 150, 151, 152, 153, 154, 155, 156, 157, 158, 159, 160, 161, 162, 163, 164, 165, 166, 167, 168, 169, 170, 171, 172, 173, 174, 175, 176, 177, 178, 179, 180, 181, 182, 183, 184, 185, 186, 187, 188, 189, 190, 191, 192, 193, 194, 195, 196, 197, 198, 199, 200, 201, 202, 203, 204, 205, 206, 207, 208, 209, 210, 211, 212, 213, 214, 215, 216, 217, 218, 219, 220, 221, 222, 223, 224, 225, 226, 227, 228, 229, 230, 231, 232, 233, 234, 235, 236, 237, 238, 239, 240, 241, 242, 243, 244, 245, 246, 247, 248, 249, 250, 251, 252, 253, 254, 255, 256, 257, 258, 259, 260, 261, 262, 263, 264, 265, 266, 267, 268, 269, 270, 271, 272, 273, 274, 275, 276, 277, 278, 279, 280, 281, 282, 283, 284, 285, 286, 287, 288, 289, 290, 291, 292, 293, 294, 295, 296, 297, 298, 299, 300, 301, 302, 303, 304, 305, 306, 307, 308, 309, 310, 311, 312, 313, 314, 315, 316, 317, 318, 319, 320, 321, 322, 323, 324, 325, 326, 327, 328, 329, 330, 331, 332, 333, 334, 335, 336, 337, 338, 339, 340, 341, 342, 343, 344, 345, 346, 347, 348, 349, 350, 351, 352, 353, 354, 355, 356, 357, 358, 359, 360, 361, 362, 363, 364, 365, 366, 367, 368, 369, 370, 371, 372, 373, 374, 375, 376, 377, 378, 379, 380, 381, 382, 383, 384, 385, 386, 387, 388, 389, 390, 391, 392, 393, 394, 395, 396, 397, 398, 399, 400, 401, 402, 403, 404, 405, 406, 407, 408, 409, 410, 411, 412, 413, 414, 415, 416, 417, 418, 419, 420, 421, 422, 423, 424, 425, 426, 427, 428, 429, 430, 431, 432, 433, 434, 435, 436, 437, 438, 439, 440, 441, 442, 443, 444, 445, 446, 447, 448, 449, 450, 451, 452, 453, 454, 455, 456, 457, 458, 459, 460, 461, 462, 463, 464, 465, 466, 467, 468, 469, 470, 471, 472, 473, 474, 475, 476, 477, 478, 479, 480, 481, 482, 483, 484, 485, 486, 487, 488, 489, 490, 491, 492, 493, 494, 495, 496, 497, 498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, 509, 510, 511, 512, 513, 514, 515, 516, 517, 518, 519, 520, 521, 522, 523, 524, 525, 526, 527, 528, 529, 530, 531, 532, 533, 534, 535, 536, 537, 538, 539, 540, 541, 542, 543, 544, 545, 546, 547, 548, 549, 550, 551, 552, 553, 554, 555, 556, 557, 558, 559, 560, 561, 562, 563, 564, 565, 566, 567, 568, 569, 570, 571, 572, 573, 574, 575, 576, 577, 578, 579, 580, 581, 582, 583, 584, 585, 586, 587, 588, 589, 590, 591, 592, 593, 594, 595, 596, 597, 598, 599, 600, 601, 602, 603, 604, 605, 606, 607, 608, 609, 610, 611, 612, 613, 614, 615, 616, 617, 618, 619, 620, 621, 622, 623, 624, 625, 626, 627, 628, 629, 630, 631, 632, 633, 634, 635, 636, 637, 638, 639, 640, 641, 642, 643, 644, 645, 646, 647, 648, 649, 650, 651, 652, 653, 654, 655, 656, 657, 658, 659, 660, 661, 662, 663, 664, 665, 666, 667, 668, 669, 670, 671, 672, 673, 674, 675, 676, 677, 678, 679, 680, 681, 682, 683, 684, 685, 686, 687, 688, 689, 690, 691, 692, 693, 694, 695, 696, 697, 698, 699, 700, 701, 702, 703, 704, 705, 706, 707, 708, 709, 710, 711, 712, 713, 714, 715, 716, 717, 718, 719, 720, 721, 722, 723, 724, 725, 726, 727, 728, 729, 730, 731, 732, 733, 734, 735, 736, 737, 738, 739, 740, 741, 742, 743, 744, 745, 746, 747, 748, 749, 750, 751, 752, 753, 754, 755, 756, 757, 758, 759, 760, 761, 762, 763, 764, 765, 766, 767, 768, 769, 770, 771, 772, 773, 774, 775, 776, 777, 778, 779, 780, 781, 782, 783, 784, 785, 786, 787, 788, 789, 790, 791, 792, 793, 794, 795, 796, 797, 798, 799, 800, 801, 802, 803, 804, 805, 806, 807, 808, 809, 810, 811, 812, 813, 814, 815, 816, 817, 818, 819, 820, 821, 822, 823, 824, 825, 826, 827, 828, 829, 830, 831, 832, 833, 834, 835, 836, 837, 838, 839, 840, 841, 842, 843, 844, 845, 846, 847, 848, 849, 850, 851, 852, 853, 854, 855, 856, 857, 858, 859, 860, 861, 862, 863, 864, 865, 866, 867, 868, 869, 870, 871, 872, 873, 874, 875, 876, 877, 878, 879, 880, 881, 882, 883, 884, 885, 886, 887, 888, 889, 890, 891, 892, 893, 894, 895, 896, 897, 898, 899, 900, 901, 902, 903, 904, 905, 906, 907, 908, 909, 910, 911, 912, 913, 914, 915, 916, 917, 918, 919, 920, 921, 922, 923, 924, 925, 926, 927, 928, 929, 930, 931, 932, 933, 934, 935, 936, 937, 938, 939, 940, 941, 942, 943, 944, 945, 946, 947, 948, 949, 950, 951, 952, 953, 954, 955, 956, 957, 958, 959, 960, 961, 962, 963, 964, 965, 966, 967, 968, 969, 970, 971, 972, 973, 974, 975, 976, 977, 978, 979, 980, 981, 982, 983, 984, 985, 986, 987, 988, 989, 990, 991, 992, 993, 994, 995, 996, 997, 998, 999, 1000



Validation data

Planet Data

Planet Medres  
Normalized  
Analysis 2020-12  
MosaicPlanet Medres  
Normalized  
Analysis 2020-11  
Mosaic

## Select Driver(s)

Artisanal Agriculture

Settlements

Infrastructure

Artisanal Mine

Industrial Mine

Artisanal Forestry

Industrial Forestry

Industrial Agriculture

Other



Change Type

## Add additional information

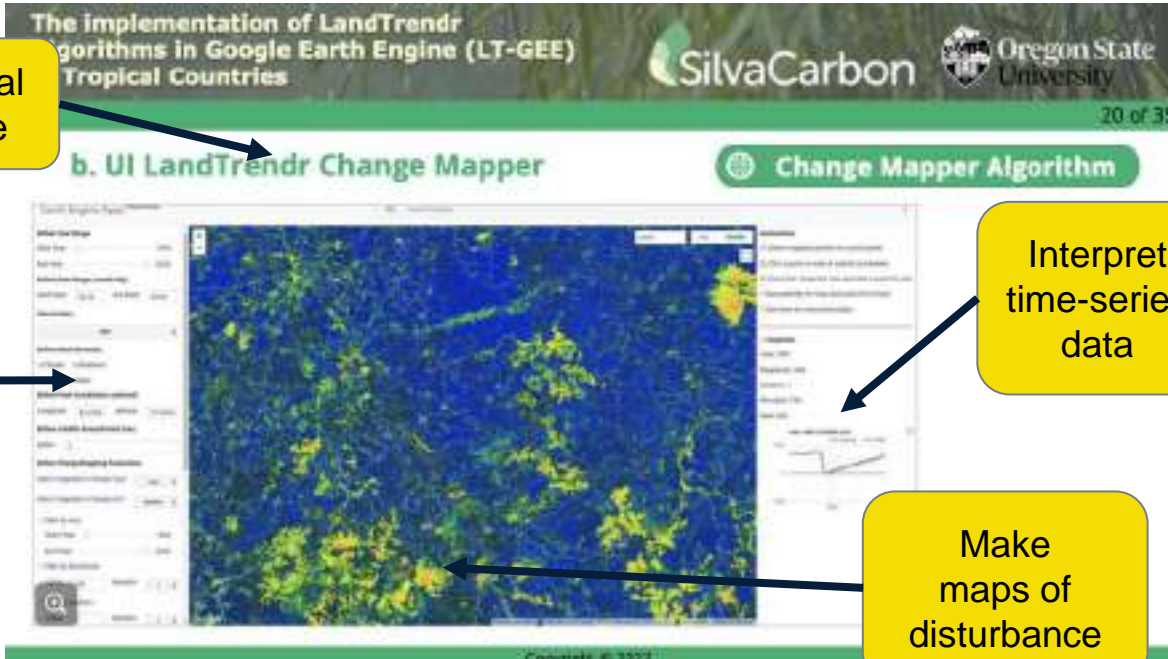
Comment on validation data



To enter information on a plot, select it in the map

# LandTrendr summary

## Example: What you'll learn about mapping forest disturbance



The implementation of LandTrendr algorithms in Google Earth Engine (LT-GEE) Tropical Countries

SilvaCarbon Oregon State University

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b. UI LandTrendr Change Mapper

Change Mapper Algorithm

Control algorithm behavior

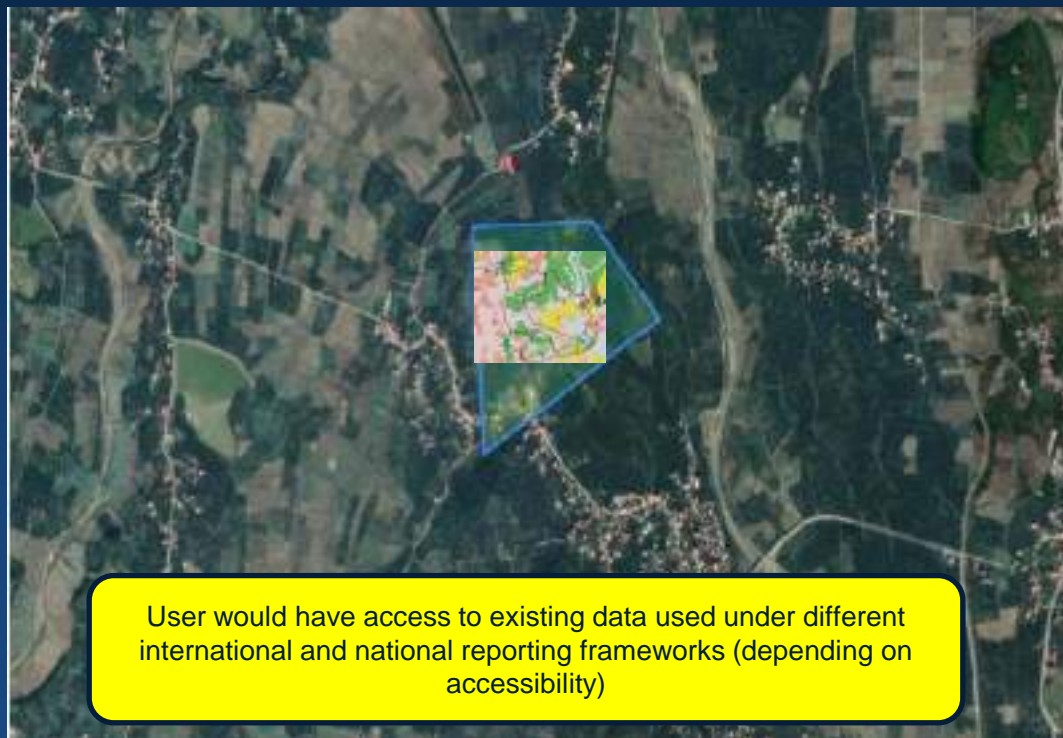
Interpret time-series data

Make maps of disturbance

Use a graphical user interface



# A FERM Platform for monitoring terrestrial ecosystem restoration



User would have access to existing data used under different international and national reporting frameworks (depending on accessibility)

## Area of Interest

- GADM/GAUL
- Upload your AOI
- Design your AOI

## Layers by ecosystem components

- Soil
- Water
- Vegetation

## Layers by climatic zone

- Subtropical
- Temperate
- Dry
- Tropical

## Prepare your indices

- Link to modules in SEPAL
- Download (.shp, .tif, .kml, .xls, etc.)

# Different frameworks, similar indicators, same data?



Convention on  
Biological Diversity



United Nations  
Framework Convention on  
Climate Change



United Nations  
Convention to Combat  
Desertification



And others

We map frameworks related to ecosystem restoration and develop a database which contains the data, indicators, criteria, targets, etc.



Food and Agriculture  
Organization of the  
United Nations

# The Forest Data Partnership

*Eliminating Supply Chain Deforestation and Catalyzing Ecosystem Restoration*

## Work streams



**Engage partners  
and stakeholders**



**Align on  
foundational  
data gaps**



**Innovate  
demand-driven  
approaches**



**Deploy  
data delivery  
mechanisms**



**Assess  
impact**

## Dimensions

5 years – 2022 to 2026  
\$ 6.2 million



## Monitoring and policy needs (here and now)

- Better data, better decisions? E.g. 10 years of UN-REDD
- Need for (better) integration of measurable field, airborne and space borne RS parameters with practical land/forest (monitoring) solutions and policy implementation
- Support research needed in the domains of agriculture, food security, raw materials, soils, biodiversity, environmental degradation and hazards, inland and coastal waters, and forestry
- **Mitigation** efforts versus **adaptation**: new monitoring field to be explored, f. e. agricultural practices/management through Chl, N in soils

# TAKE HOME MESSAGES and link with EO

-**Agriculture, forestry and other land use** can not only **provide large-scale GHG emissions reductions, but also absorb and store CO<sub>2</sub> at scale**. Agroforestry, reforestation, avoiding deforestation, managing soils and sustainable livestock management can enhance productivity, improve livelihoods and provide renewable energy.

-Positive impacts of certain **international and climate policies** on reducing emissions have been shown as for example deforestation, it argues that it is too early to say whether zero-deforestation pledges from the public and private sectors can be effective.

-- Achieving ambitious climate goals relies on **international cooperation**. Transnational partnerships are playing a growing role as technology, knowledge and experience are shared.

-**Earth Observation with long data records** and data over remote places can help in

- Validation of (climate and other) models
- Monitoring and early warning: imaging spectroscopy!
- Process understanding
- Importance of free and open EO data

## AI/Earth Observation for global climate change : our wish list from policy side

- Support in mapping **changes in land cover/use** and help sustainable forest management and agricultural practices: ADAPTATION (monitoring)
- Detect **soil properties** for action on improving soil health
- Support **forest management** and assessments on biodiversity, ecosystem sustainability and environmental degradation, and to monitor lake and coastal ecosystems
- **New products and services** in the domain of agriculture, food security, raw materials, soils, biodiversity, environmental degradation and hazards, inland and coastal waters, and forestry, **including impact metrics** and **distinction private and public end users**

## Way forward interlinking end users and scientific community

- Taking into account **user requirements** in the domains of land and forest monitoring

- **User inclusion** from the concrete (project) start

- **Data ownership** for end users

- Important **policy frameworks**, among others

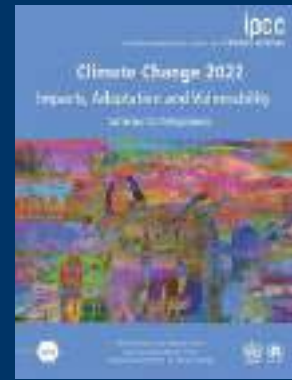
UN SDGs [SDGs 2, 12 and 15], the EU Common Agricultural Policy (CAP), the EU Raw Materials Initiative, the UN Convention for Combating Desertification and Land Degradation, the Soil Thematic Strategy and the Soil Framework Directive, the EU Water Framework Directive and the UN Convention on Biodiversity (Aichi Targets).

- Upcoming: Talk in EU Pavillion (COP 28), publication white paper on SBAE

# Sixth Assessment Report

WORKING GROUP II & III – ADAPTATION & MITIGATION OF CLIMATE CHANGE

“ The evidence is  
clear:  
The time for  
action is now





Thanks for your attention!

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inge.Jonckheere@fao.org