

Sentinels for Greener Cotton - How Earth Observation supports the Better Cotton Initiative criteria



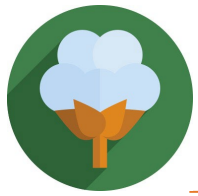
geo | cledian
spatial architects



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Making cotton more sustainable
using satellite-based digital agriculture



Scope

- ESA-funded feasibility study (2021)
- Design of analytical services supporting BCI principles based on EO & meteo data
- Pilots with textile producers, spinning companies, farm management systems
- Supply chain traceability, standardization and certification
- Extension to other commodities (RSPO Palm Oil, Rain Forest Alliance, Sustainable Sugarcane Initiative)



Overview of Better Cotton Principles

1 BCI Farmers minimise the harmful impact of **crop protection** practices

BCI supports farmers in developing a better knowledge and understanding of practices that minimise the potential harmful effects of pesticides and in adopting Integrated Pest Management technologies with an emphasis on the use of pest control techniques other than pesticides

2 BCI Farmers promote **water stewardship**

BCI supports farmers in using water efficiently to consume and pollute less water; thus achieving greater yields and building their resilience to climate change while promoting fair use and allocation of water resources amongst users beyond the farm, and up to the watershed level.

3 BCI Farmers care for the **health of the soil**

BCI supports farmers in a better understanding and use of the soil. A healthy soil leads to significant increases in the quality and quantity of yields; to large cost reductions in fertilisers, pesticides and labour; and is a main asset for climate resilience.

4 BCI Farmers enhance **biodiversity** and use **land responsibly**

BCI supports farmers in conserving and enhancing biodiversity on their land; and in adopting practices which minimise the negative impact on habitats in and around their farm.

5 BCI Farmers care for and preserve **fibre quality**

BCI supports farmers in managing inherent fibre characteristics, man-made contamination and waste content; to enhance their cotton quality, thus enhancing its value, and leading to a better price for farmers.

6 BCI Farmers promote **decent work**

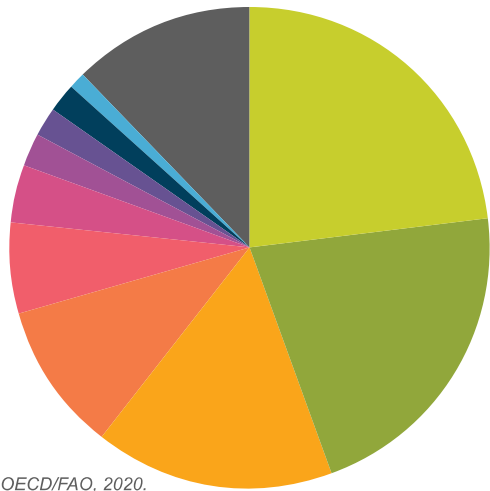
BCI supports farmers in promoting fundamental principles and rights at work on employment and income opportunities, social protection and social security, and social dialogue; based on international labour standards.

7 BCI Farmers operate an effective **management system**

BCI supports farmers in operating a management system that includes the framework of policies, processes and procedures ensuring they can fulfil all the tasks required to meet the Better Cotton Principles & Criteria; and to enable continuous improvement in farming practices.



Market opportunity



Source: OECD/FAO, 2020.

World cotton production 2018/19
26m tons



Source: ICAC, 2018a.

Identity cotton production 2017/18

19% of global cotton production in 2017/18 was identity cotton
2019/20 estimated at 25% (annual increase 10%)



BCI Requirements

ENVIRONMENTAL & ECONOMIC INDICATORS

Farmer Results 2017-18 Season



The 2017-18 farmer results provide an overview of the outcomes BCI Farmers are experiencing at field-level by participating in the BCI programme and adhering to the Better Cotton Principles and Criteria (P&C). The Better Cotton P&C provide a global definition of Better Cotton through seven key principles. Adhering to the Better Cotton P&C enables BCI Farmers to produce cotton in a way that is measurably better for people, the environment and farming communities.

BCI Farmers vs. Comparison Farmers

The farmer results presented here compare the country averages of key social, environmental and economic indicators achieved by licensed BCI Farmers to non-BCI Farmers in the same geographic area who are not participating in the BCI Programme. We refer to the latter farmers as Comparison Farmers.



Environmental indicators

- Pesticide Use**
The indicator measures the volume of active pesticide ingredient applied, per hectare of cotton cultivated.
- Synthetic Fertiliser Use**
The indicator measures the volume of synthetic fertiliser applied, per hectare of cotton cultivated.
- Organic Fertiliser Use**
The indicator measures the frequency of organic fertiliser use.
- Water Use for Irrigation**
The indicator measures the volume of water used for irrigation, per hectare of cotton cultivated. Water use is not recorded for rain-fed cotton cultivation.

Economic indicators

- Yield**
The indicator measures the amount of harvested cotton, per hectare.
- Profitability**
The indicator measures profitability, defined as the net income earned from producing the cotton crop.

In the 2017-18 season, the Better Cotton Standard System was directly implemented in 12 countries. This overview shares results from five of those countries and not the others for the following reasons.

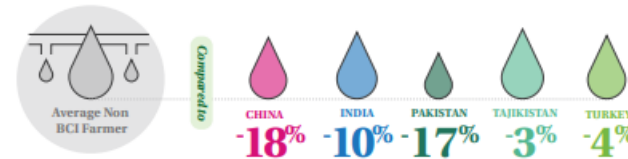
In Israel, Mozambique and South Africa, Comparison Farmer data was not available because most of the cotton farmers in these countries were already participating in the BCI Programme.

In Kazakhstan, Madagascar and Mali, there was only one licensed Producer Unit (a grouping of BCI Farmers) and BCI's data confidentiality agreements prevent public reporting of a single Producer Unit's results.

In the US, BCI only works with large farms, and Comparison Farmer data is not available because it is considered commercially confidential information.

Water m²/ha

BCI Farmers in all five countries used **LESS** water for irrigation than Comparison Farmers.

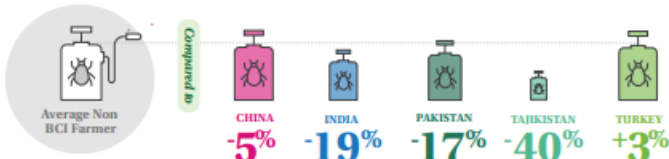


"Tip" How to talk about the results:

BCI Farmers in China used 18% less water than Comparison Farmers.

Pesticide kg/ha

BCI Farmers used **LESS** pesticide than Comparison Farmers in 4 of the 5 countries.

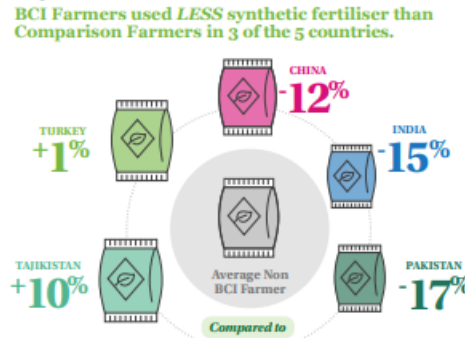


"Tip" How to talk about the results:

BCI Farmers in India used 19% less pesticide than Comparison Farmers.

Synthetic fertiliser kg/ha

BCI Farmers used **LESS** synthetic fertiliser than Comparison Farmers in 3 of the 5 countries.

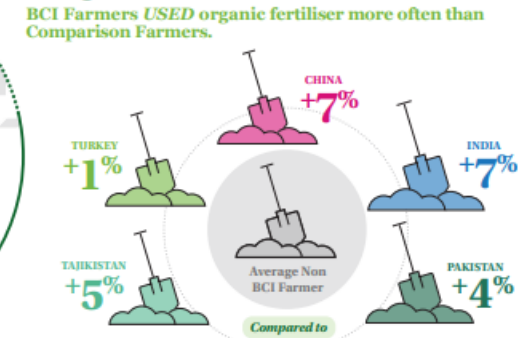


"Tip" How to talk about the results:

BCI Farmers in Pakistan used 17% less synthetic fertiliser than Comparison Farmers.

Organic fertiliser yes/no

BCI Farmers **USED** organic fertiliser more often than Comparison Farmers.

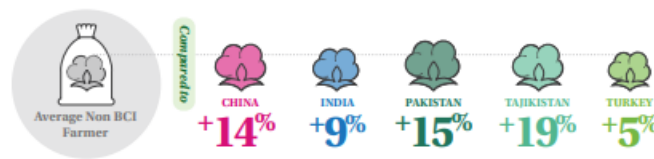


"Tip" How to talk about the results:

In Pakistan, BCI Farmers used organic fertiliser 4% more often than Comparison Farmers.

Yield lint mt/ha

BCI Farmers in all five countries had **HIGHER** yields than Comparison Farmers.

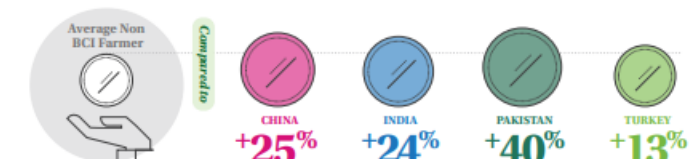


"Tip" How to talk about the results:

BCI Farmers in Tajikistan had a 19% higher yield than Comparison Farmers.

Profit net income/ha

BCI Farmers in 4 of the 5* countries had **HIGHER** profits than Comparison Farmers.



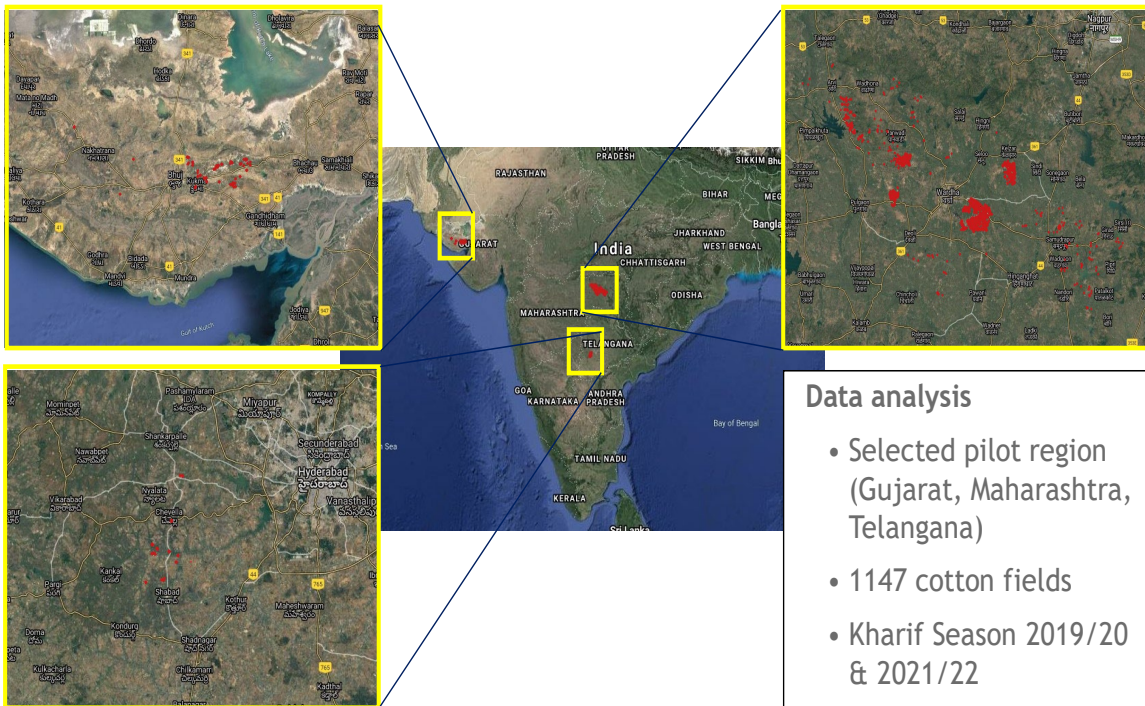
"Tip" How to talk about the results:

BCI Farmers in Turkey had 13% higher profits than Comparison Farmers.

*Due to data quality challenges with Comparison Farmers, the profitability indicator for this season has been omitted for Tajikistan.

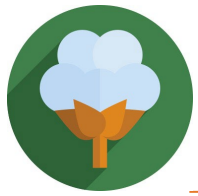


Pilot areas

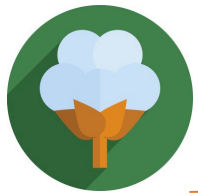


| Region | Kharif season | Parcel count | total area [ha] |
|--------------|---------------|--------------|-----------------|
| Gujarat | 2019/2019 | 9 | 11.43 |
| Maharashtra | 2019/2020 | 190 | 71.27 |
| Telangana | 2019/2020 | 6 | 6.71 |
| total | | 205 | 89.41 |
| Gujarat | 2021/2021 | 262 | 1830.63 |
| Maharashtra | 2021/2022 | 671 | 1960.22 |
| Telangana | 2021/2022 | 9 | 7.67 |
| total | | 730 | 2142.52 |

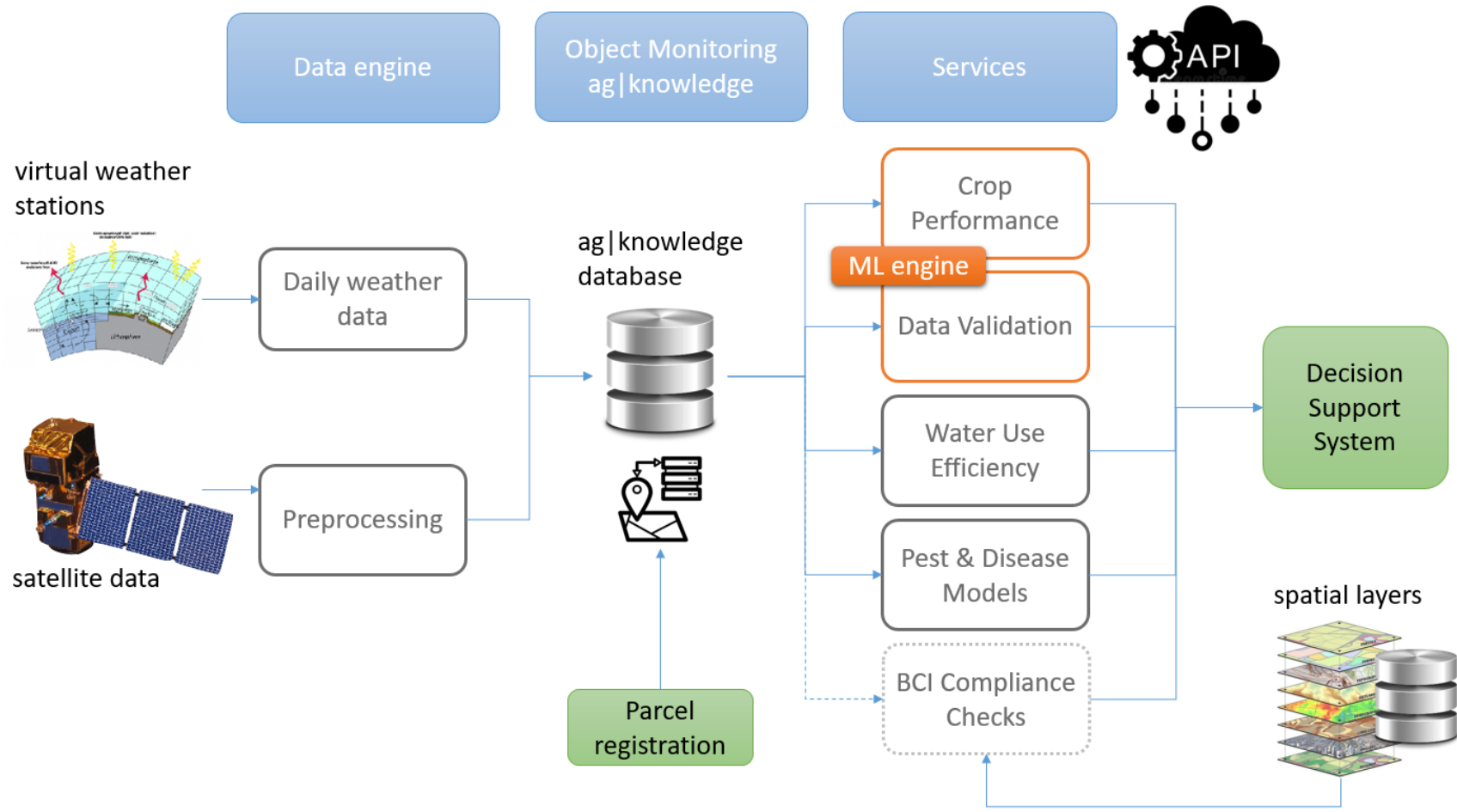
Partners: WelSpun & SourceTrace

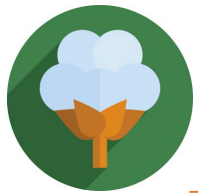


1. **Data Validation:** verification of sowing, cropped area, declared crop type
2. **Crop Performance & Production Monitor:** biomass index, field benchmarking, peak of season measurement, yield assessment
3. **Agronomic Weather Service:** forecast and weather recording
4. **Water Use Efficiency Monitoring:** water availability and irrigation advisory
5. **Pest & Disease Risk Assessment:** disease risk models based on weather
6. **Land Responsibility:** BCI Conversion, mapping of natural resources, compliance

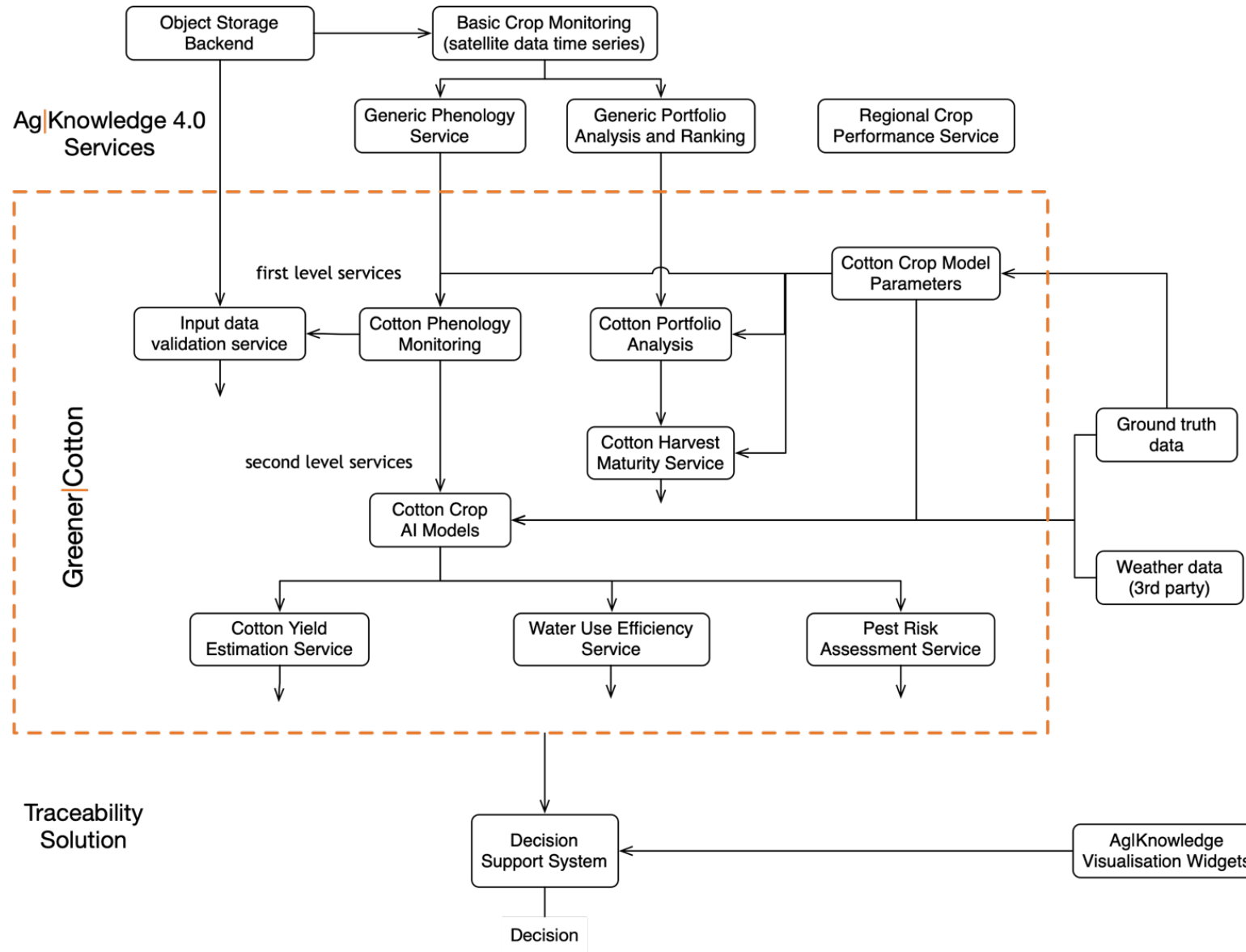


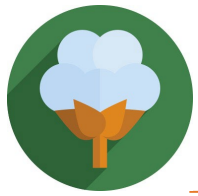
ag | knowledge System



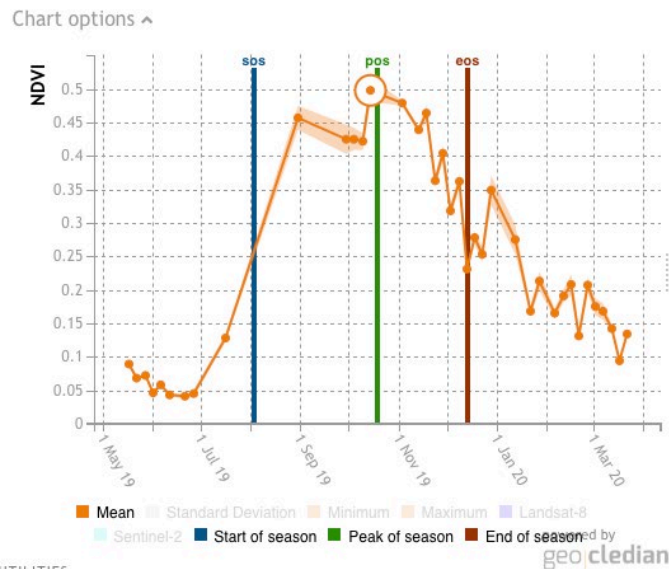
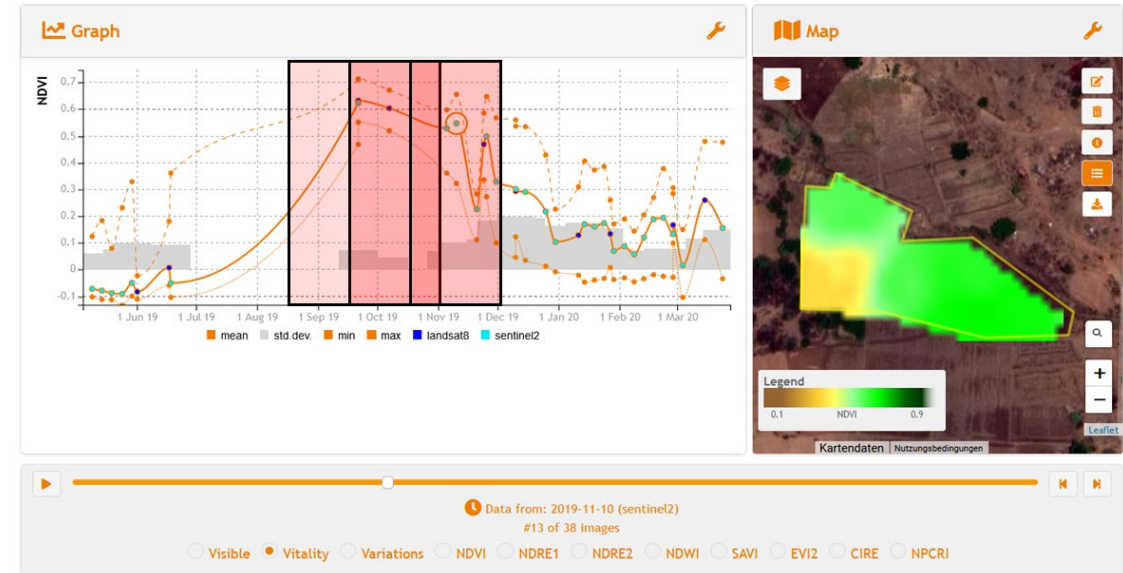
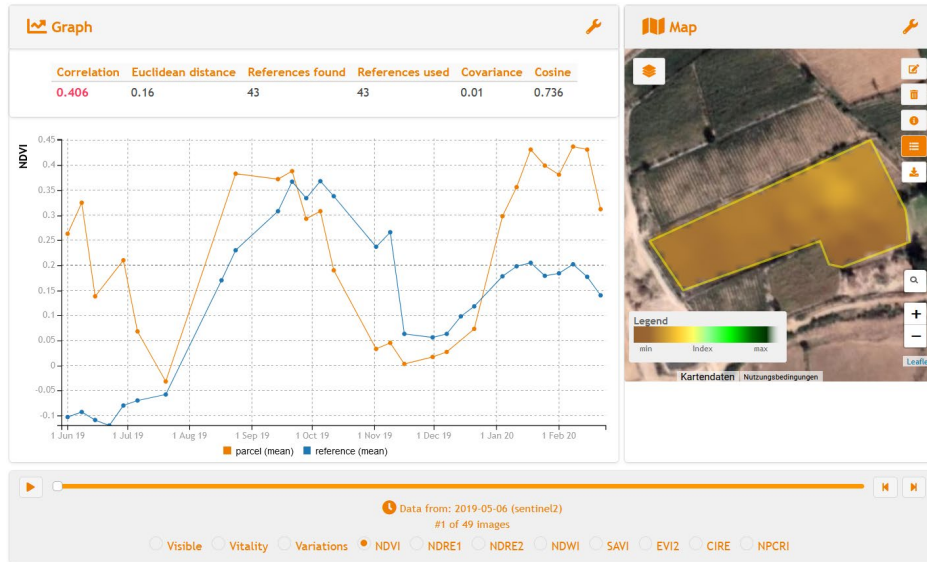


EO Services Design

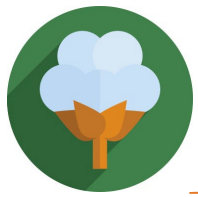




Validation Service



- area under crops check
- land use homogeneity check
- crop type validation → high feasibility (if in-situ data is provided for ML training, else: association of phenology markers with crop calendar)
- seeding date check (requires data reliability)



Validation Service

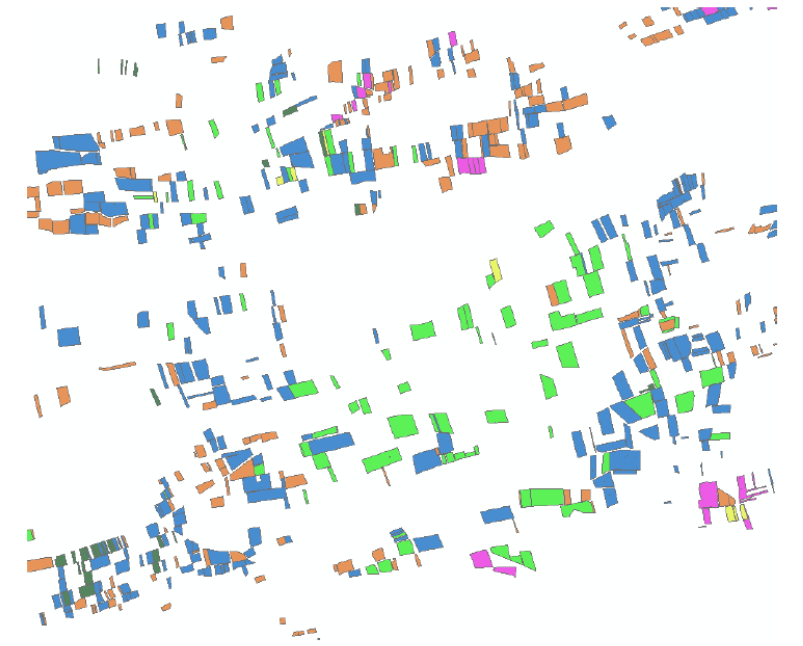
Verification of cotton varieties

- Timing: mid season (POS)
- Targeted overall level of accuracy 80-90%

Notes:

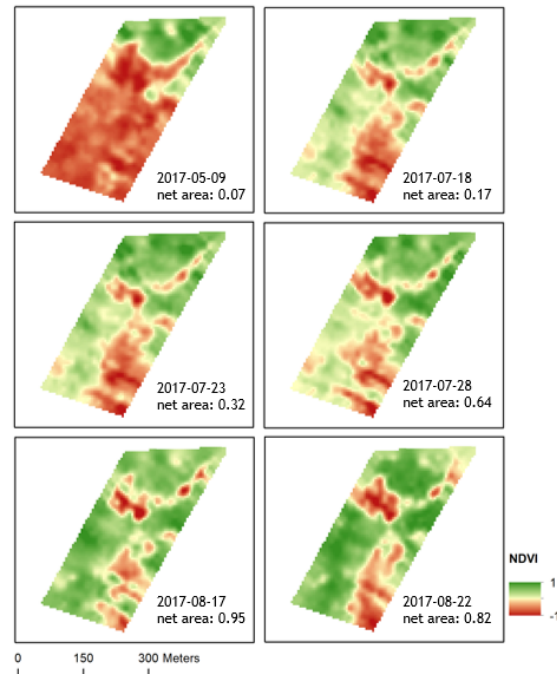
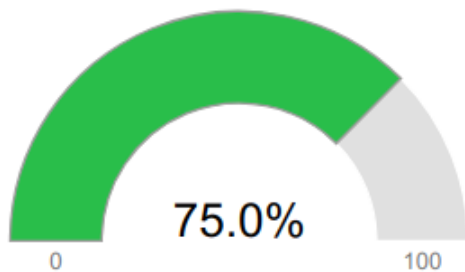
- Annual training data > 50 fields per variety/crop and climatic zone for high accuracy required

- AKH 081
- LH 900
- LSS
- P 216 F
- 320 F
- Rs 875



Verification of actual (net) cultivated area

75% of overall area emerged

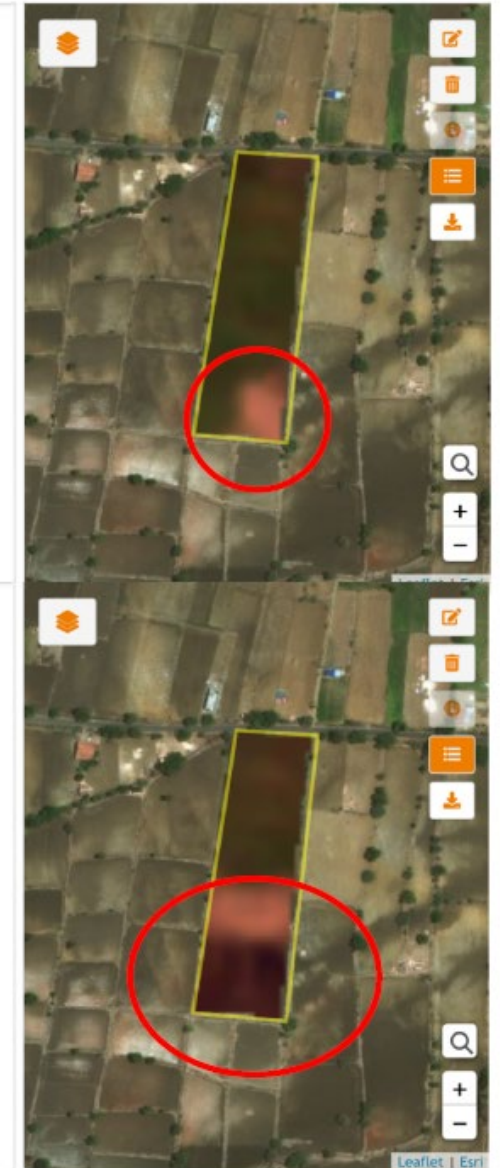
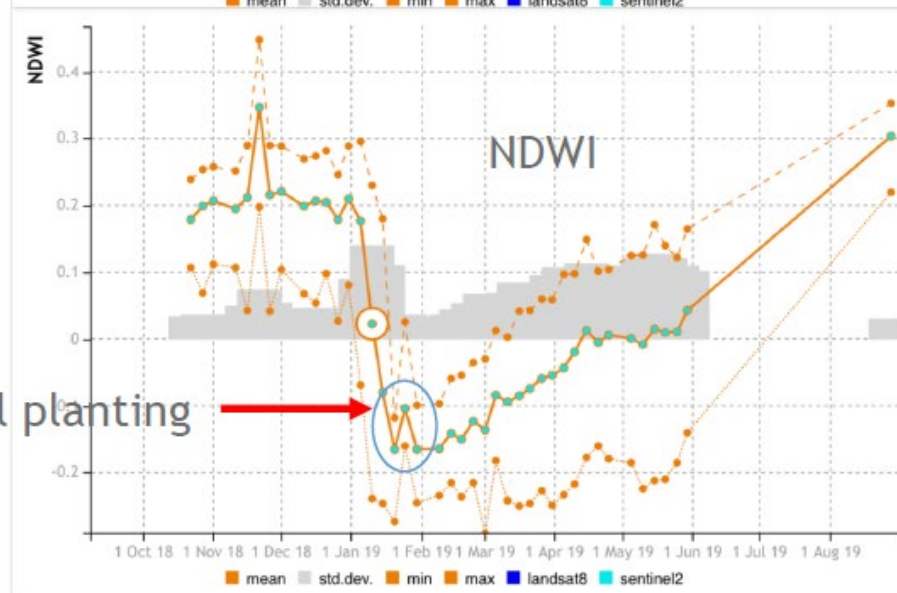
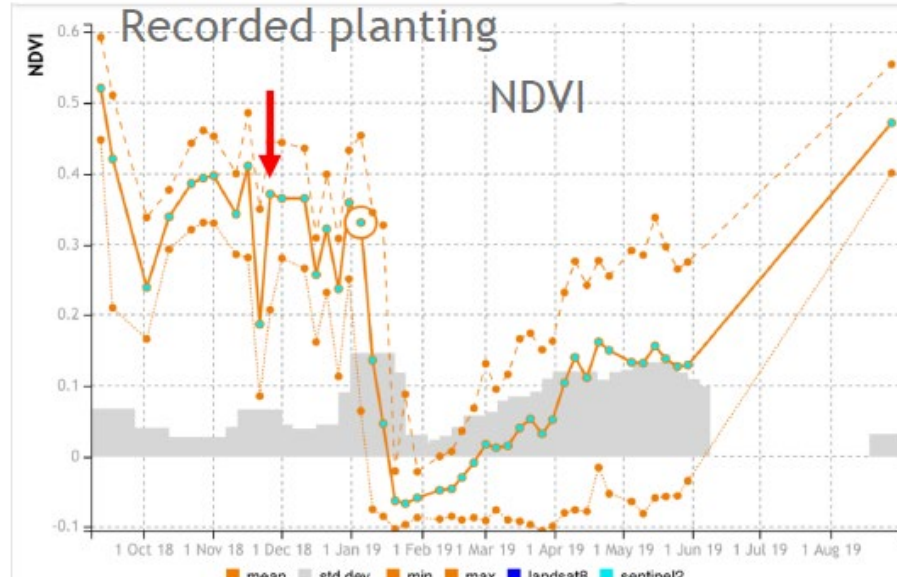


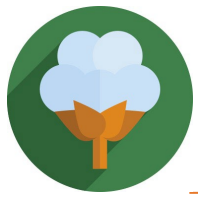


Verification of Planting Dates

Planting recorded:
20.11.2018

- Last year harvest starts at 05.01.2019
- Planting starts around **10.01.2019** (while harvest continues)
- **Incorrect** planting date recorded





Verification of Harvesting Dates

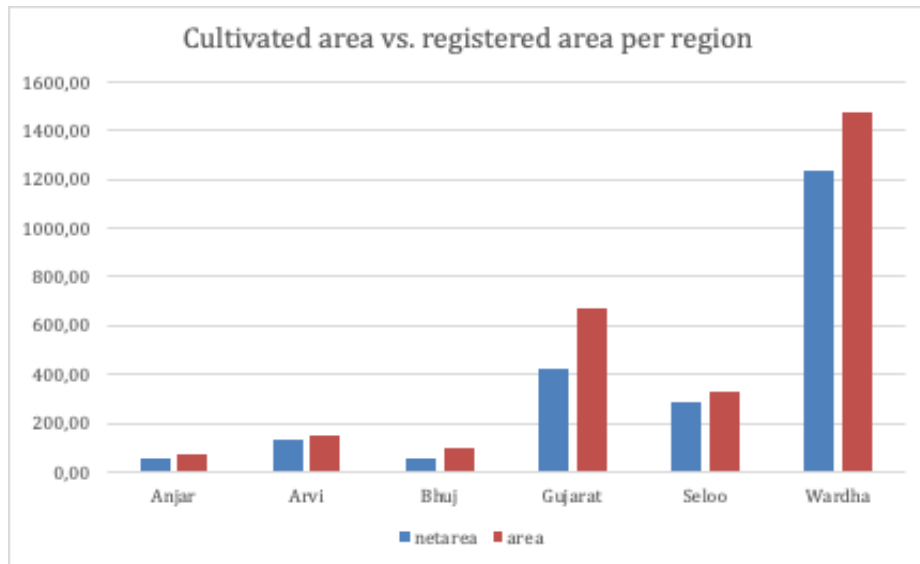
Harvest date recorded: 2018-11-29

found: 2018-12-26

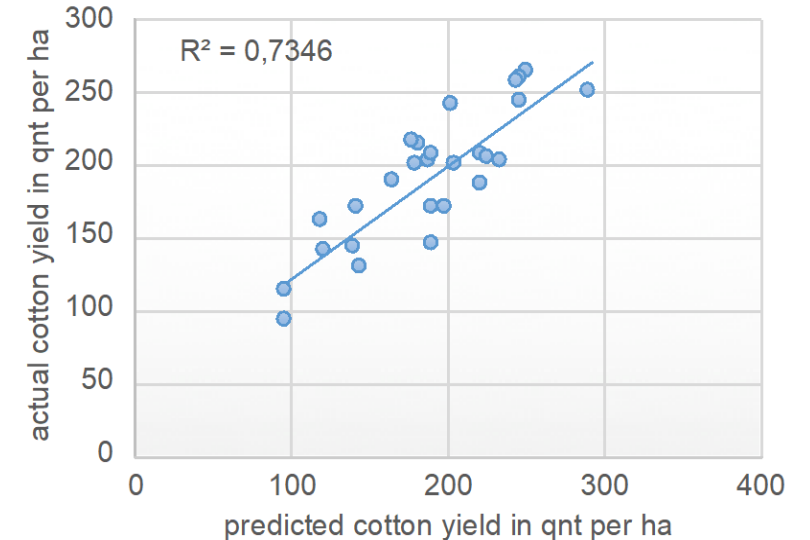




Crop Performance Service



| Season 2019/2020 | | |
|---------------------------|-----------|-----------|
| Bottom Ten Cotton Parcels | | |
| Ranking Date = 2019-09-15 | | |
| Rank | Parcel ID | NDVI mean |
| 189 | 17831 | 0.41 |
| 190 | 17814 | 0.41 |
| 191 | 17819 | 0.41 |
| 192 | 17829 | 0.41 |
| 193 | 17781 | 0.40 |
| 194 | 17833 | 0.40 |
| 195 | 17764 | 0.40 |
| 196 | 17765 | 0.39 |
| 197 | 17821 | 0.38 |
| 198 | 17797 | 0.32 |



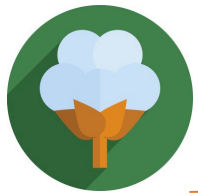
- crop rotation identification → due to cloud cover in India, Sentinel-1 is necessary
- cultivated area estimation → also derives the gross outputs
- biomass and yield estimation
- crop phenology identification



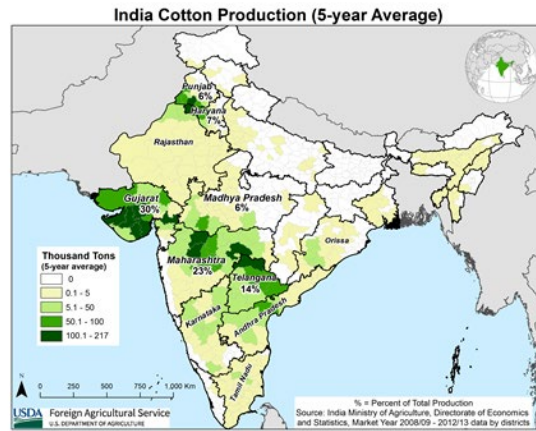
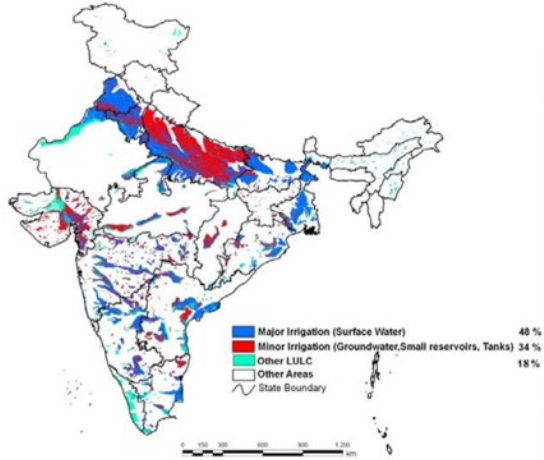
Variables

- temperature (mean, min, max)
- precipitation (sum)
- soil moisture at 0-10cm (mean, min, max)
- soil temperature at 0-10cm (mean, min, max)
- evapotranspiration (ET0, sum)
- horizontal radiation (sum)
- dew point temperature (mean, min, max)
- wind speed (mean, min, max)
- main wind direction
- relative humidity (mean, min, max)

- VWST daily updates tested (best available model resolution 12 km)
- 7 days forecast

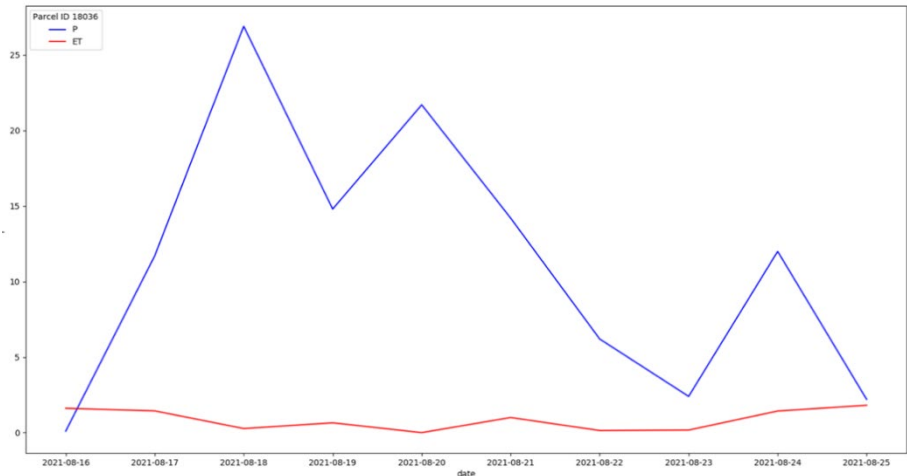


Water Use Service & Drought monitor



| Water Balance | | | | | | | | | | |
|---------------|-------------|---------------|---------------|---------------|--------------|---------------|--------------|---------------|-------------|--------------|
| parcel_id | 16.08.2021 | 17.08.2021 | 18.08.2021 | 19.08.2021 | 20.08.2021 | 21.08.2021 | 22.08.2021 | 23.08.2021 | 24.08.2021 | 25.08.2021 |
| 18033 | ◆ -0.14 | ◆ 7.24 | ● 34.44 | ▲ 19.39 | ◆ 9.83 | ● 34.02 | ▲ 9.98 | ◆ -0.31 | ◆ -0.73 | ◆ 0.31 |
| 18034 | ◆ 1.34 | ◆ 8.28 | ● 33.76 | ▲ 24.09 | ▲ 10.77 | ● 23.99 | ▲ 10.83 | ◆ -0.04 | ◆ -0.2 | ◆ 0.07 |
| 18035 | ◆ 1.05 | ◆ 8.16 | ● 33 | ▲ 20.13 | ▲ 4.73 | ● 30.17 | ▲ 10.3 | ◆ -0.59 | ◆ -1.74 | ◆ -0.62 |
| 18036 | ◆ -1.51 | ▲ 10.26 | ● 26.63 | ▲ 14.15 | ▲ 21.7 | ▲ 13.2 | ◆ 6.06 | ▲ 2.23 | ▲ 10.57 | ◆ 0.39 |
| 18037 | ◆ -1.4 | ▲ 10.49 | ● 27.13 | ▲ 14.07 | ▲ 21.47 | ● 23.1 | ◆ 6.07 | ◆ -0.48 | ◆ -1.06 | ◆ -1.11 |
| 18038 | ◆ 2.02 | ● 27.82 | ● 23.98 | ▲ 20.39 | ▲ 21.64 | ● 32.65 | ◆ 3 | ◆ -2.18 | ◆ 0.56 | ◆ -1.55 |
| 18039 | ◆ 2.02 | ● 27.82 | ● 23.98 | ▲ 20.39 | ▲ 21.64 | ● 32.65 | ◆ 3 | ◆ -2.18 | ◆ 0.56 | ◆ -1.55 |
| 18040 | ◆ 2.02 | ● 27.82 | ● 23.98 | ▲ 20.39 | ▲ 21.64 | ● 32.65 | ◆ 3 | ◆ -2.18 | ◆ 0.56 | ◆ -1.55 |
| 18041 | ◆ 2.02 | ● 27.82 | ● 23.98 | ▲ 20.39 | ▲ 21.64 | ● 32.65 | ◆ 3 | ◆ -2.18 | ◆ 0.56 | ◆ -1.55 |
| 18042 | ◆ 2.02 | ● 27.82 | ● 23.98 | ▲ 20.39 | ▲ 21.64 | ● 32.65 | ◆ 3 | ◆ -2.18 | ◆ 0.56 | ◆ -1.55 |
| total | 9.44 | 183.53 | 274.86 | 193.78 | 176.7 | 287.73 | 58.24 | -10.09 | 9.64 | -8.71 |

- weather-based water balance and water availability indicators based on weather models
- MODIS & Sentinel-3-based regional drought risk assessment
- needed: parcel-level ETa data for water use efficiency



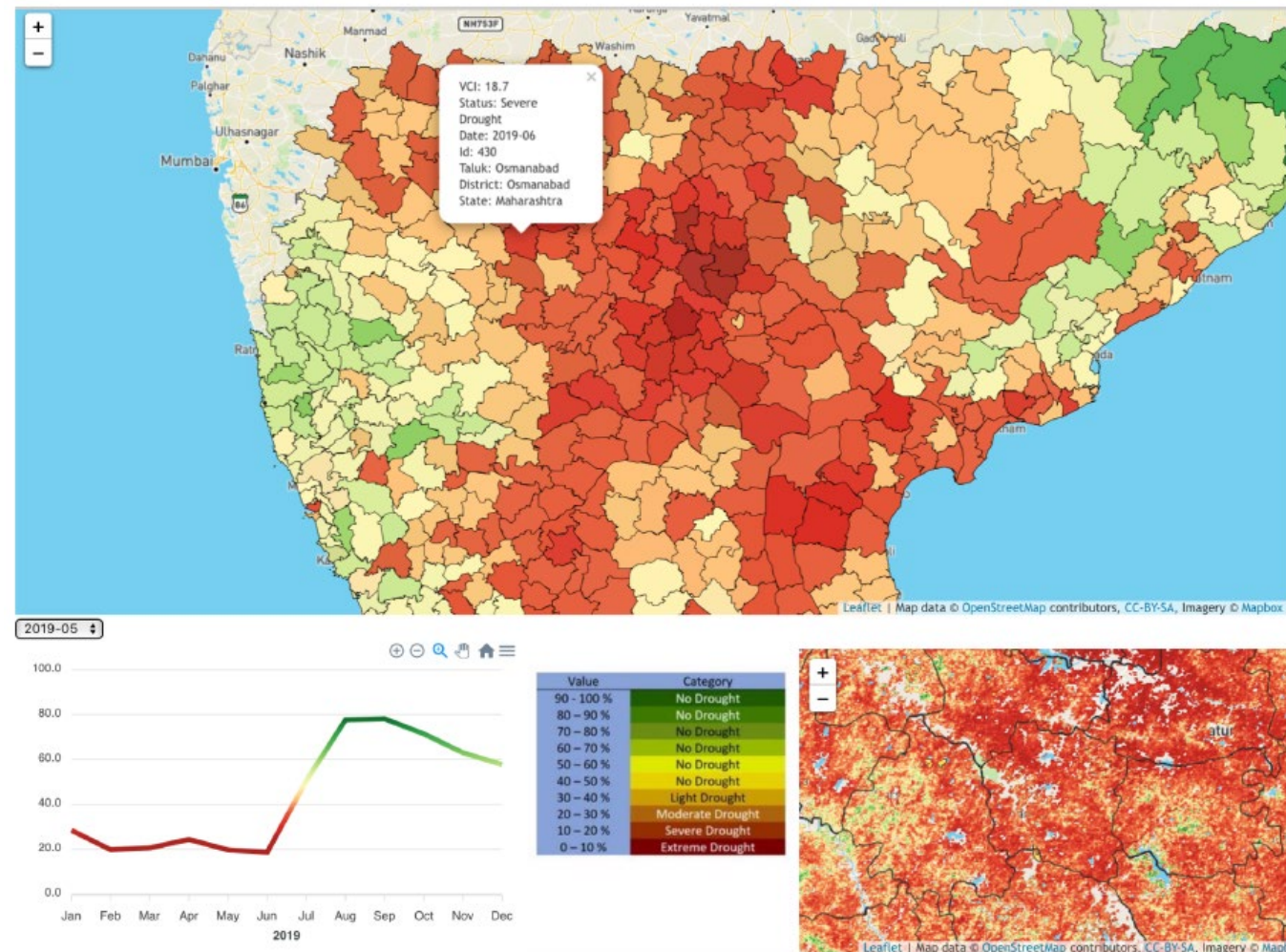


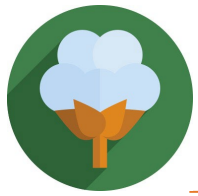
Identification and localization of drought, flood and cyclone/storm damage

- **Drought Monitoring Service** per revenue circle and village, indicates severness of drought
- **Updated 8 days** during dry season possible

Benefits

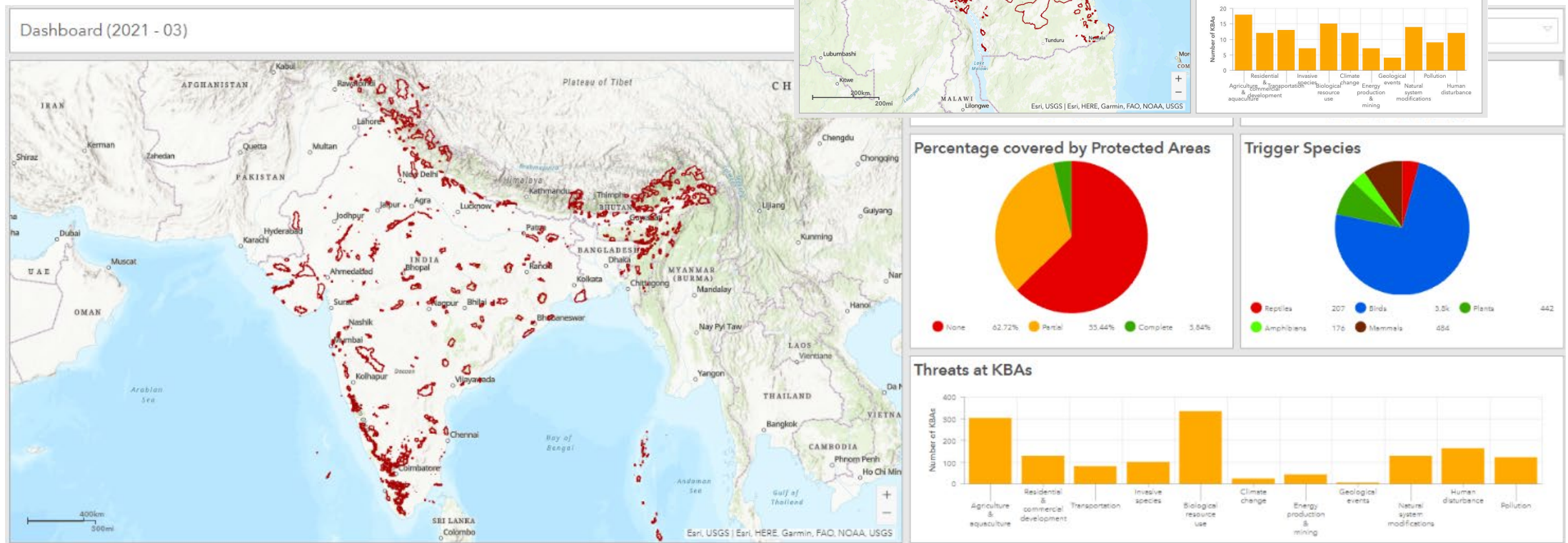
- Monitoring drought situation at admin. level
- Improving irrigation advisory
- Mitigating damage and crop failures





Land Responsibility Service

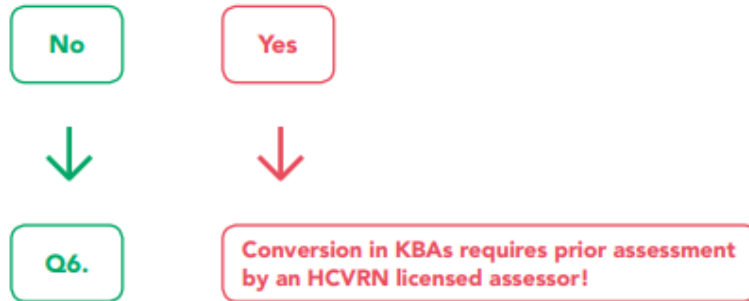
- Key Biodiversity Areas (KBA)
- Intact Forest Landscapes (IFL)
- Protected Areas (IUCN)



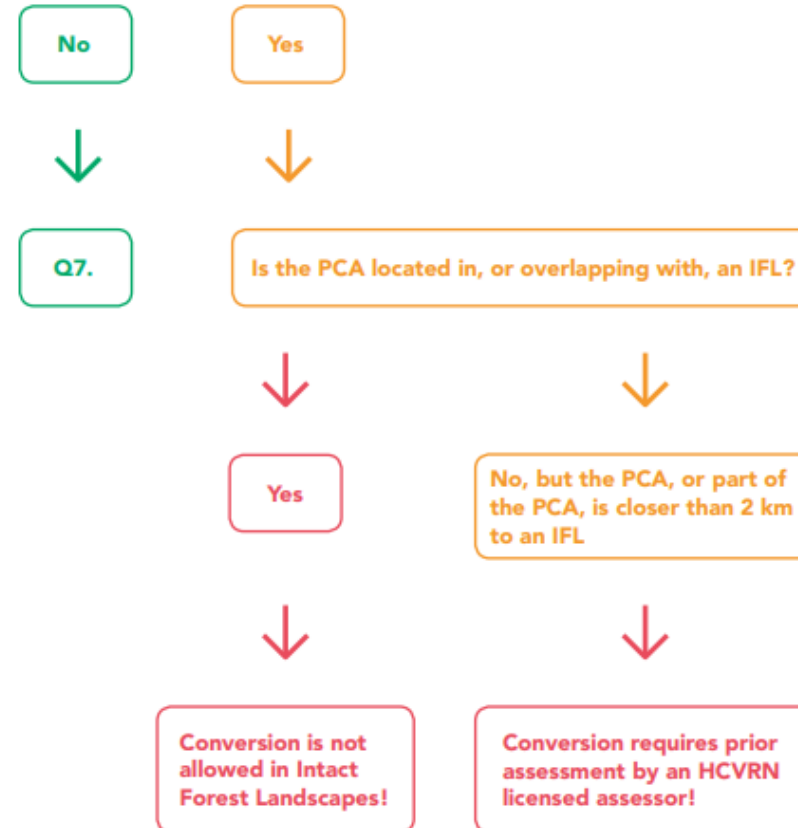


Land Responsibility Service

Q5: Is the PCA located in a Key Biodiversity Area (KBA)?



Q6: Is the PCA located in, or closer than 2 km to, an Intact Forest Landscape (IFL)?



Q12A: Does the proposed conversion require clearing of trees or bushes with stem diameter > 10 cm?



Q12B: Has the PCA been used for crop cultivation any time over the last 3 years?



Q12C: Will the cultivation of the PCA require measures to drain excess water?





Q7: Is any part of the PCA closer than 100 m to a river, stream, ditch, canal, pond or lake?

No



Q8.

Yes



Elevated Risk: Cultivation close to open water may cause leakage of pesticides, fertilisers and suspended particles, with negative impacts on water quality at and downstream the point of pollution. To mitigate such impacts, maintain (or restore) a buffer zone of perennial vegetation adjacent to the water body or stream, at least 10 meters wide (or as wide as the water course, whatever is the larger number). Do not clear, plant or use any pesticides or fertilisers in the buffer zone, and do not dump waste or sewage.



Mitigation measures should be agreed upon with the Production Unit Manager and the Water Management Plan should be accordingly updated.



Q8.

Q8: Is any part of the PCA situated on a steep slope (> 1 m vertical in 4 m horizontal)?

No



End of risk assessment for Smallholders!

Yes



Elevated Risk: Clearing and cultivation on steep slopes increases the risk of soil erosion, mudslides and landslides after heavy rain. Areas on slopes may only be converted on the condition that mitigation measures, appropriate to the soil and rainfall characteristics, are identified and implemented. Measures may include terracing, minimising the amount of exposed soil without vegetation cover, channelling of rain water, use of sedimentation traps, agroforestry to take advantage of soil stabilization by tree roots, use of perennial crops etc.



Mitigation measures should be agreed upon with the Production Unit Manager and the Soil Management Plan should be accordingly updated.



End of risk assessment for Smallholders!



Feasibility Assessment

| Req. ID | Service Requirement | Explanation | Compliance |
|---------|--------------------------------|---|------------|
| SR-0100 | Determine cultivated area | Works with proposed methods | Full |
| SR-0200 | Check Homogeneity | Works with proposed methods. Need reflecting the cotton phenology | Full |
| SR-0300 | Check Cotton | Works sufficiently with proposed methods. | Full |
| SR-0400 | Check Crop Rotation | Works with proposed methods | Full |
| SR-0500 | Provide agronomic weather data | External provider. Higher resolution useful if available | Full |
| SR-0600 | Provide emergence confirmation | Works technically, but might be impacted by cloudy data. Consider S1 usage. Not as important as SR-0100 | Partially |
| SR-0700 | Biomass index | Works well in irrigated areas (most cotton areas). Is impacted by cloudy data in e.g. Maharashtra. Consider S1 usage. | Partially |
| SR-0800 | Field benchmarking | Based on biomass index, restrictions see above | Partially |
| SR-0900 | Determine order of harvest | Works with proposed methods | Full |
| SR-1000 | Actual evapotranspiration | Achievable by modelling. Other methods optional | Full |
| SR-1100 | Provide seasonal water balance | Can be provided based on SR-1000 and SR-0500. | Full |
| SR-1200 | Irrigation Advice | Quality considered as sufficient for smallholder farming. Higher accuracies by usage of IoT sensors achievable for industrial farming | Full |
| SR-1300 | Regional Drought Assessment | Works with proposed methods | Full |
| SR-1400 | Assess disease risk | Works up to a certain level. Should not become core service | Partial |
| SR-2000 | Yield Assessment | Targeted services will improve current knowledge sufficiently | Full |
| SR-2100 | Land Responsibility | Proven technology | Full |
| SR-3000 | Provide Visualization | Software implementation topic only | Full |



Novelty detection pipeline

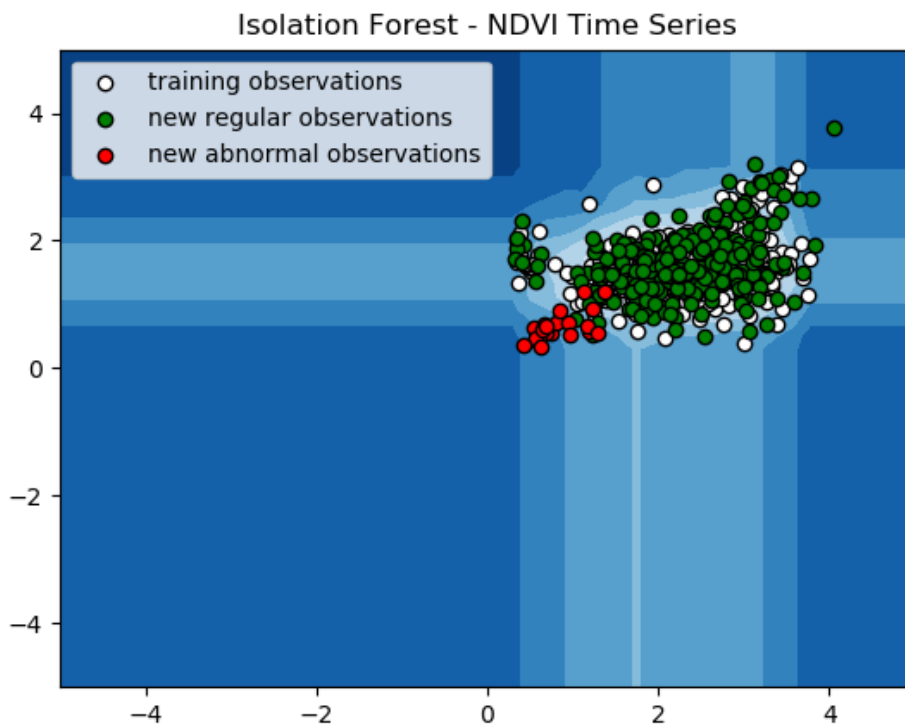
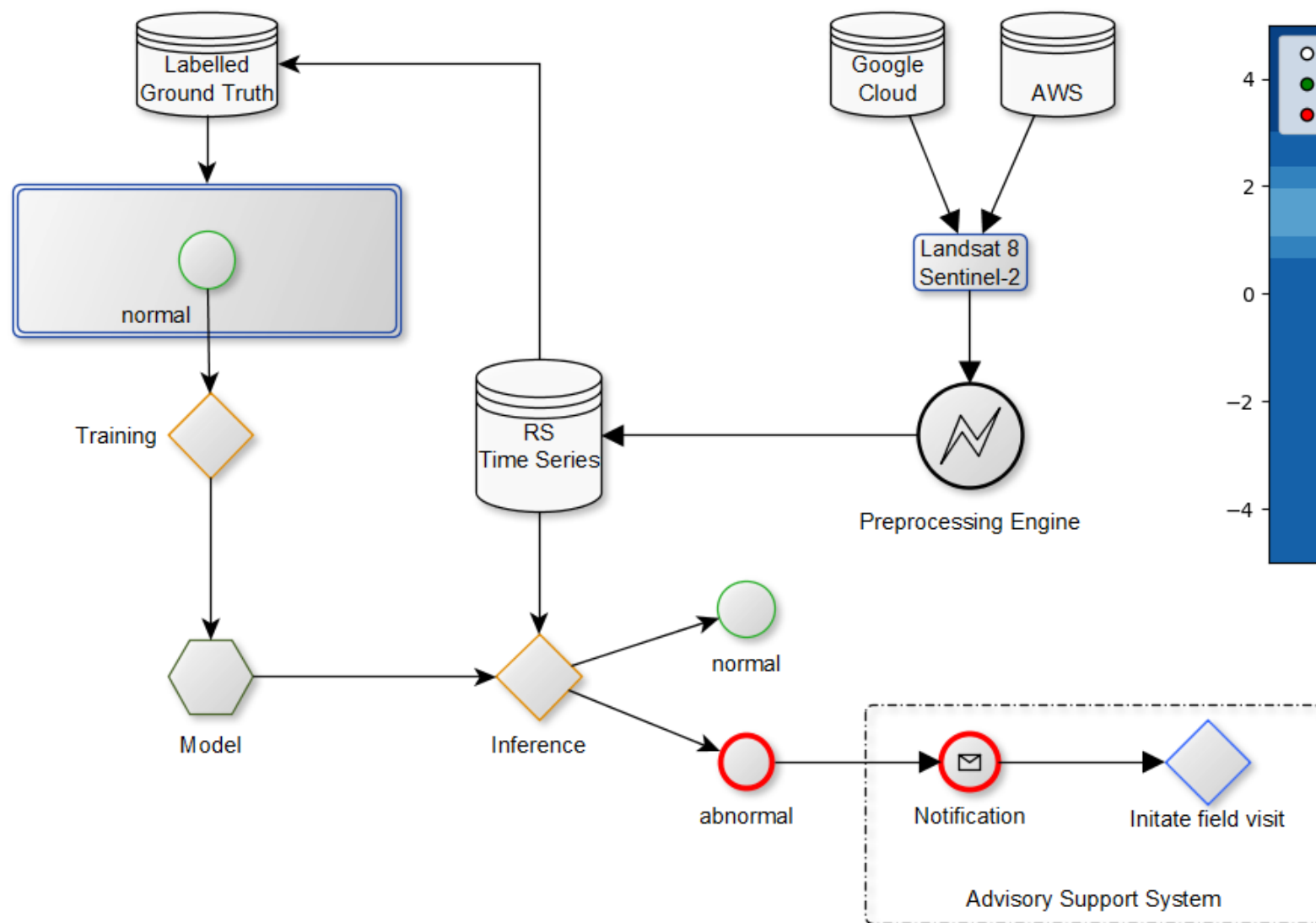
- verification of soil friendly (and resilient) cotton varieties
- identification of crop damage or other critical disturbances
- verification of non-GMO cotton varieties
- detection of chemical application or crop protection activities
- detection of abnormal irrigation or management practices

negative ground truth is rare or sometimes even impossible →

OneClass SVM, IsolationForest

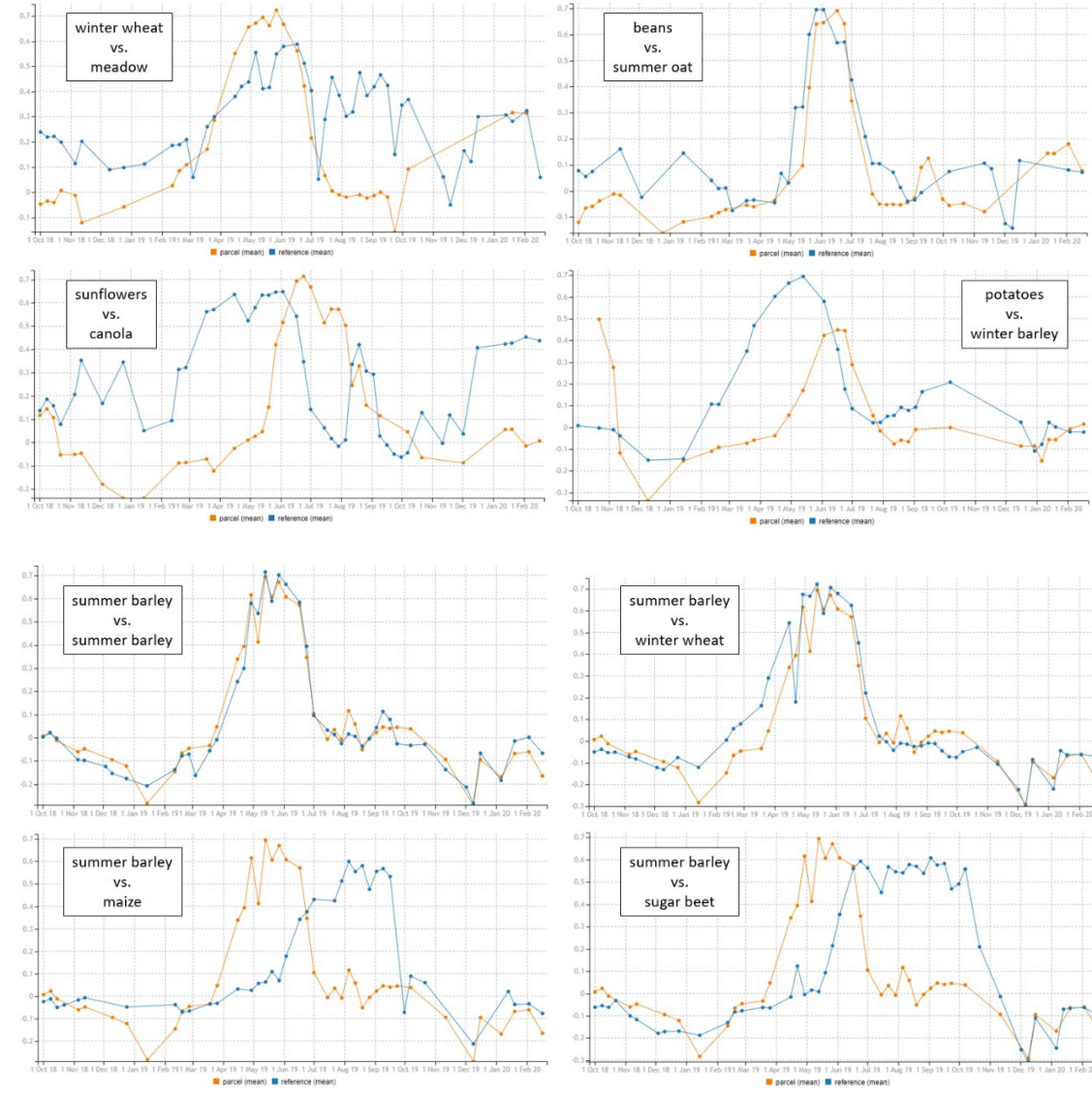
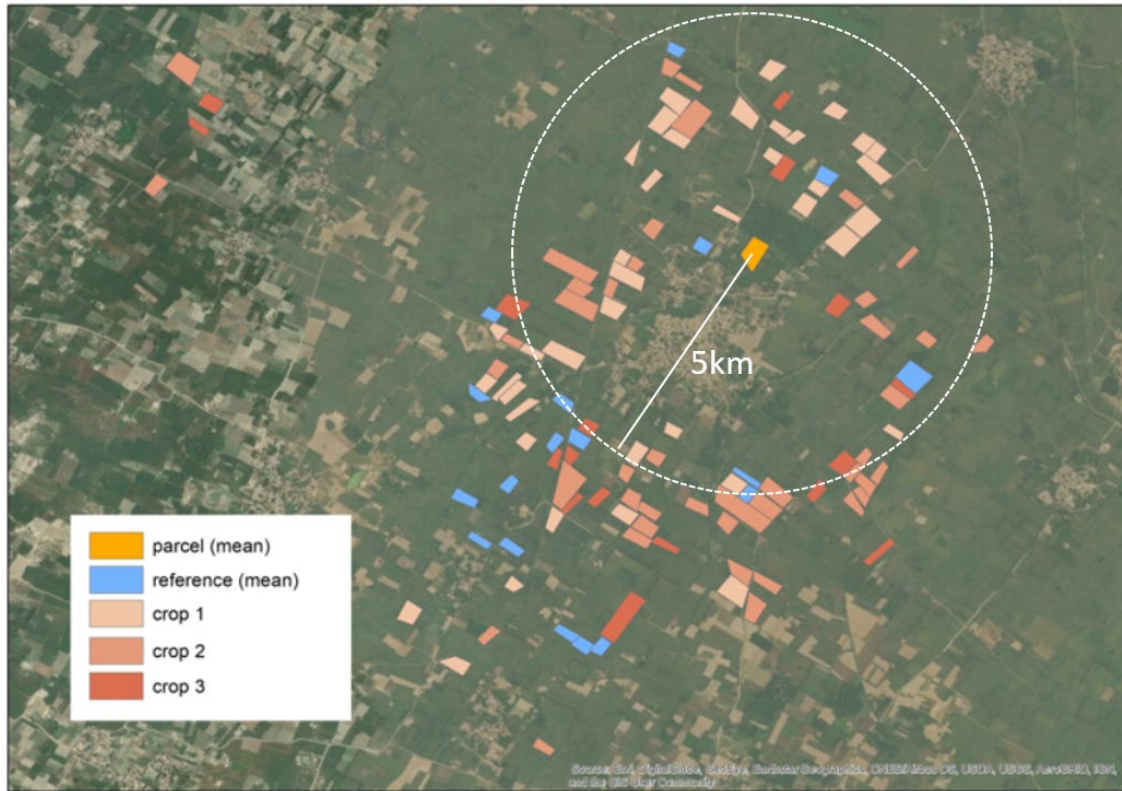


Novelty detection pipeline



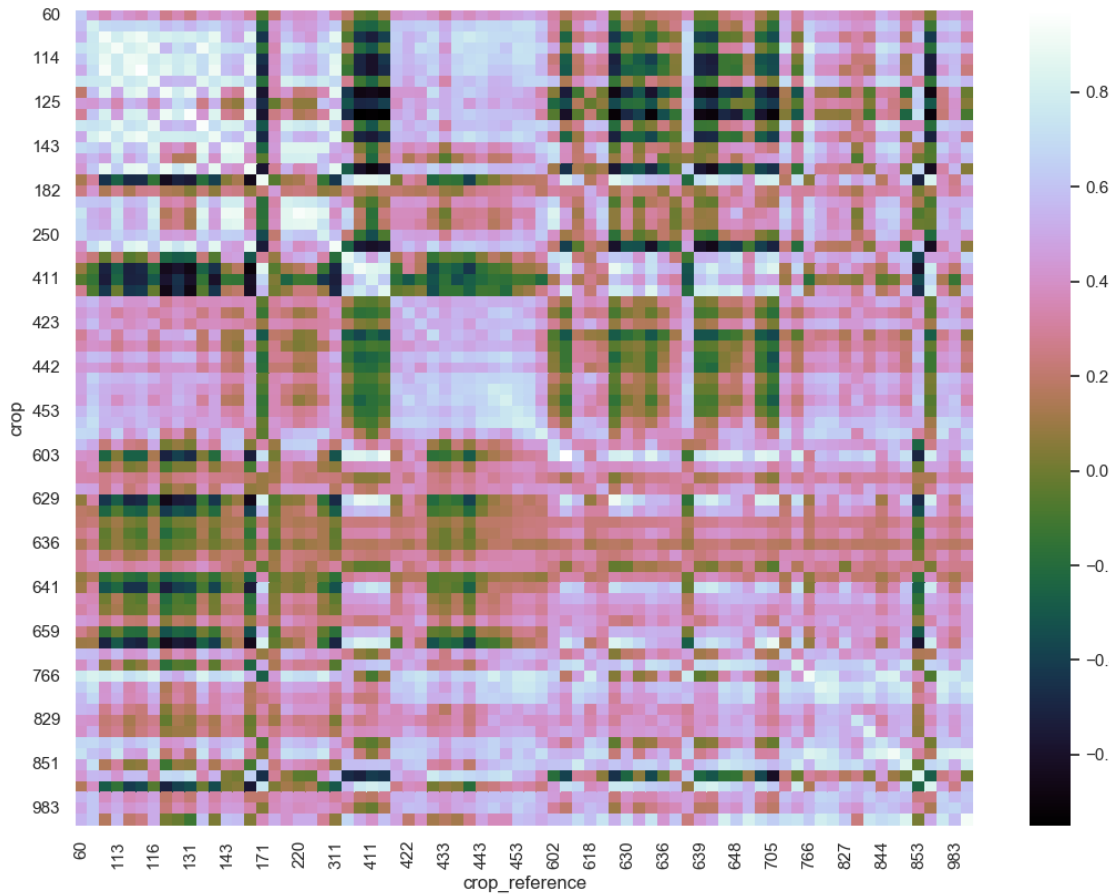


Similarity metrics pipeline

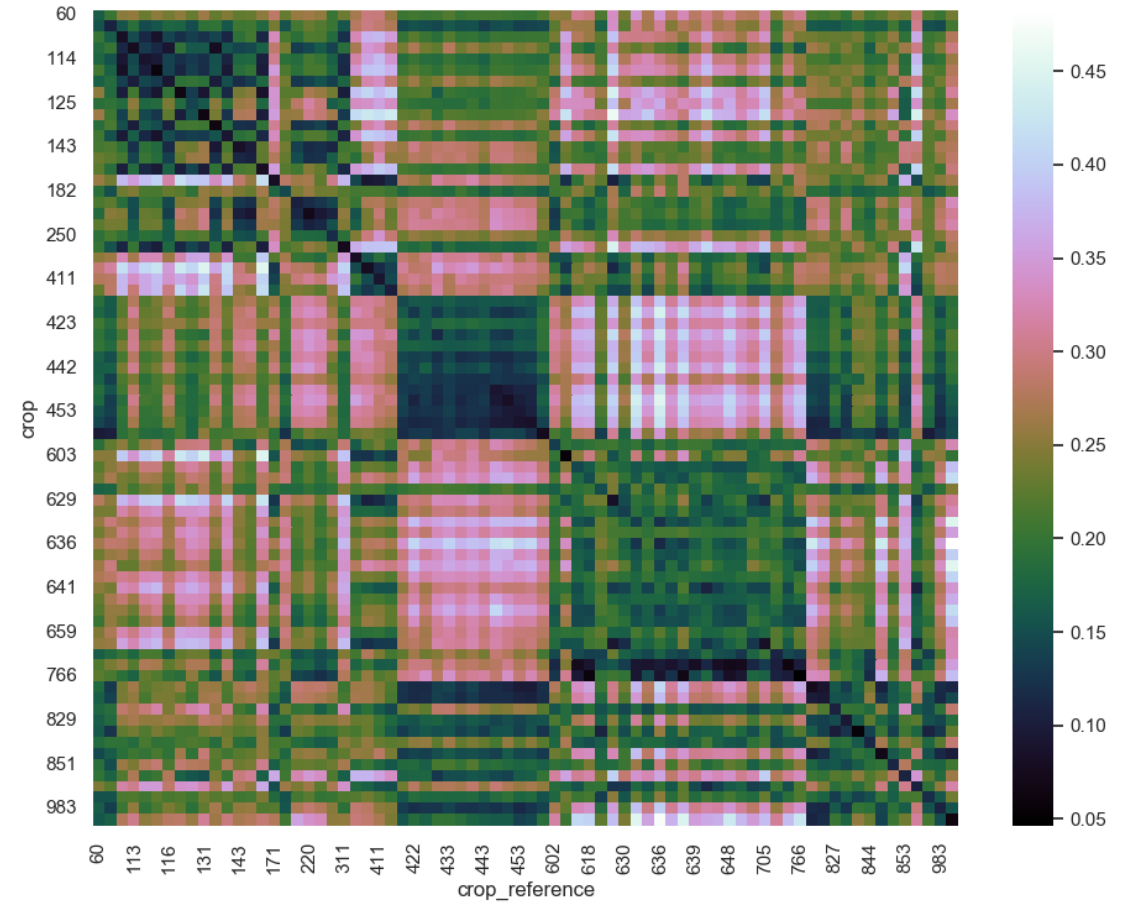




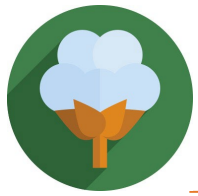
Similarity metrics pipeline



pearson correlation coefficient



mean chebyshev distance



Conclusions

- Remote Sensing services **contribute** significantly **to a better compliance**, understanding and monitoring of BCI requirements like water stewardship, soil conservation and fibre quality
- The integration of **spatial compliance checks** supports biodiversity and land responsibility criteria for the land conversion (e.g. no cotton parcel should be located within a Key Biodiversity Area)
- Remote Sensing services are **independent tools for traceability** and supply chain applications



Conclusions

Thank you for your attention!

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