Uncertainty at Scale

How computer science *hinders* climate science

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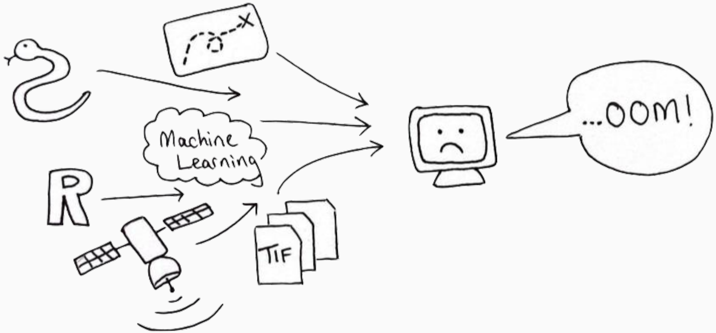
Intro

Scientific Methodologies in the Computational Age



Uncertainty

> *Just as yesterday's uncommon knowledge becomes today's common knowledge, so yesterday's unrecognized ignorance becomes today's specified ignorance.*

— Robert K. Merton [4]

Context

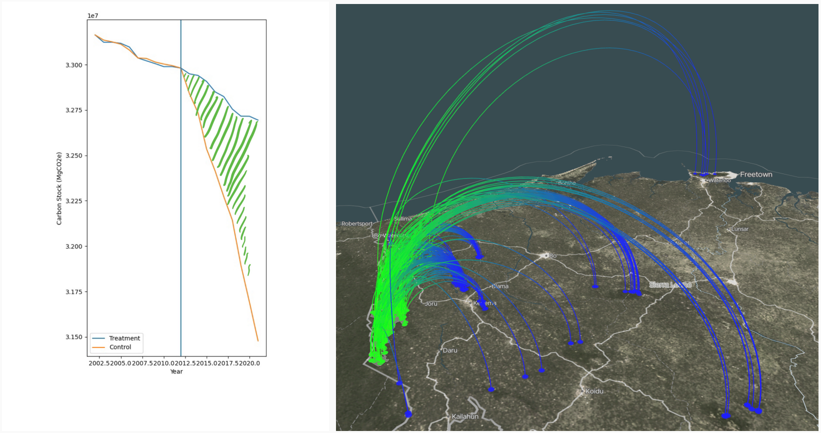


Figure 1: Additional carbon as calculated from a counterfactual analysis of a tropical moist forest avoided deforestation project

Uncertainty in Data

Tropical Moist Forests

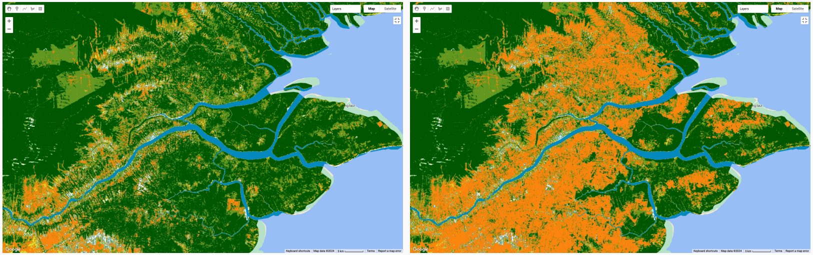


Figure 2: European Commission JRC Tropical Moist Forest Dataset from 2021 (left) and 2022 (right) for the year 2008 in Indonesia [6][1]. Legend: 🟩 undisturbed, 🟩 degraded, 🟧 deforested, 🟨 regrowth, 🟦 water, ⬜ other

[1]Source code: *`https://github.com/quantifyearth/jrc-diff`*

Indonesia in Numbers

Table 1: Changes in Land Use Class (LUC) as a percentage of the total area of Indonesia (1.9 million km^2)

LUC	2021	2022
Undisturbed	58.39	57.80
Degraded	14.47	12.47
Deforested	7.25	10.30
Regrowth	0.37	0.55
Water	2.30	2.30
Other	17.22	16.58

Deforested misclassification is approximately the size of Togo!

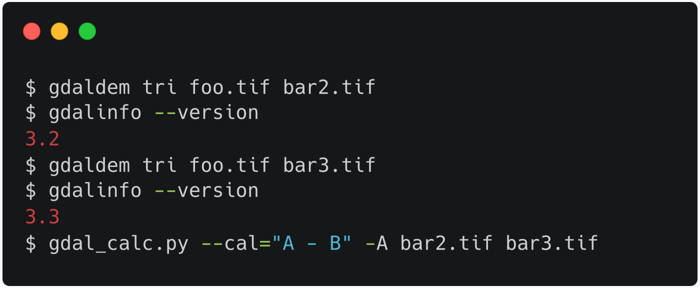
JRC TMF Changelog

- *Delineation of new tree plantation mainly in Central, West Africa, Indonesia and Malaysia.*
- *Improvements and corrections of errors in the Annual Change collection in the sequence of values for deforestation of old regrowth forest.*
- *Etc.*

European Commission Joint Research Committee [2].

Uncertainty in Code & Dependencies

System Dependencies I



```
$ gdaldem tri foo.tif bar2.tif
$ gdalinfo --version
3.2
$ gdaldem tri foo.tif bar3.tif
$ gdalinfo --version
3.3
$ gdal_calc.py --cal="A - B" -A bar2.tif bar3.tif
```

System Dependencies II

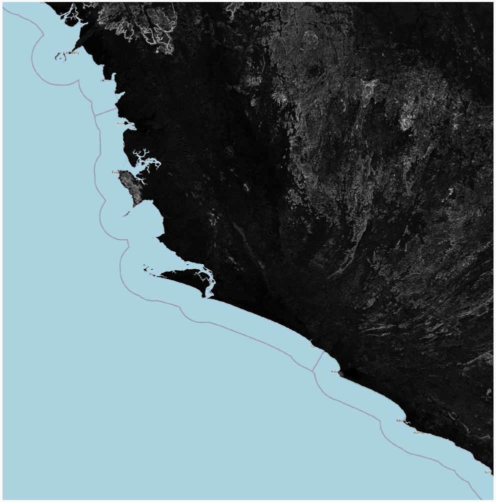
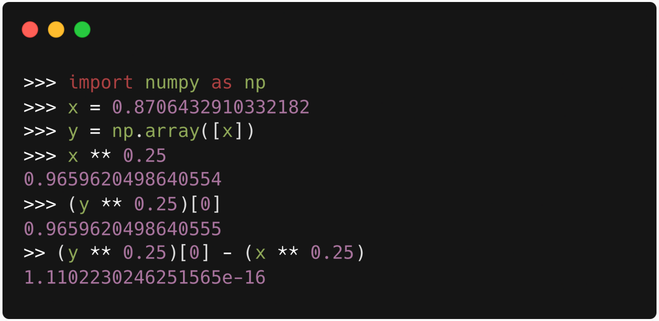


Figure 3: A case where the default algorithm for a CLI command was corrected between two minor versions of GDAL [1].

Hardware I



```
>>> import numpy as np
>>> x = 0.8706432910332182
>>> y = np.array([x])
>>> x ** 0.25
0.9659620498640554
>>> (y ** 0.25)[0]
0.9659620498640555
>> (y ** 0.25)[0] - (x ** 0.25)
1.1102230246251565e-16
```

Figure 4: Numpy floating point number inconsistencies arising from optimisations in the SVML library[2].

[2]Details: *https://github.com/numpy/numpy/issues/25269*

Hardware II

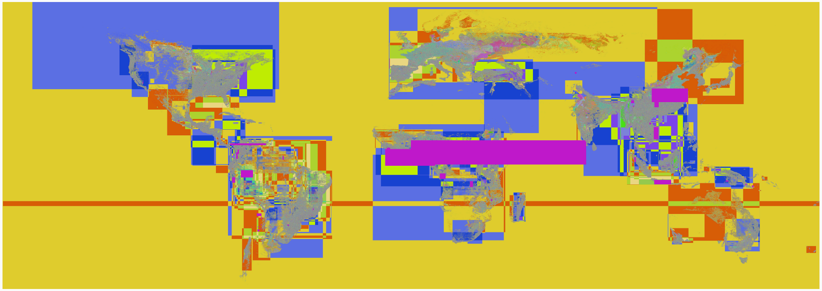
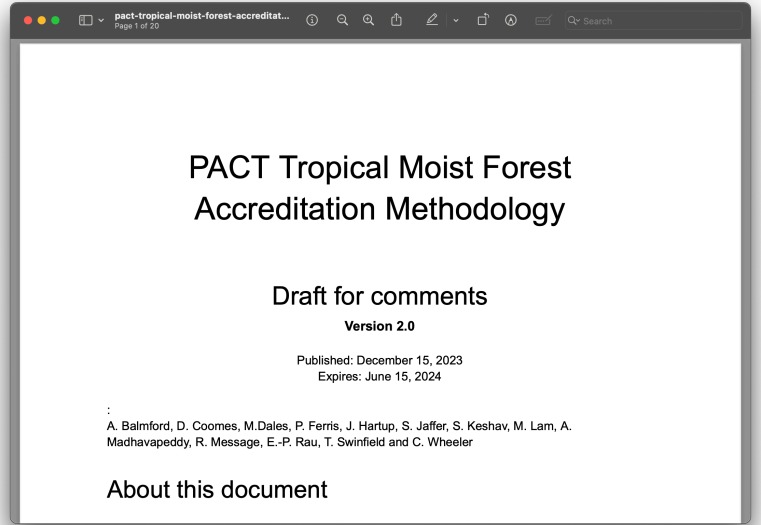


Figure 5: Whilst subepsilon values on their own may be insignificant, they can accumulate across many computations to become significant.

Uncertainty in Ecology

Communicating Methodologies I



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PACT Tropical Moist Forest Accreditation Methodology

Draft for comments

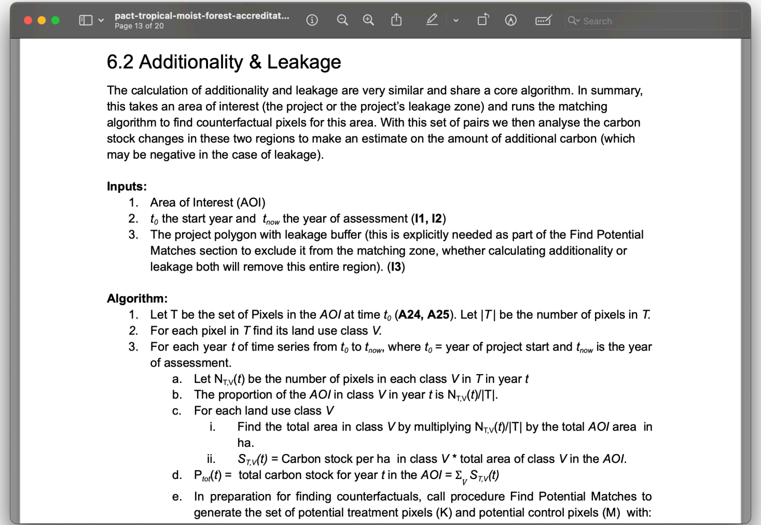
Version 2.0

Published: December 15, 2023
Expires: June 15, 2024

:
A. Balmford, D. Coomes, M.Dales, P. Ferris, J. Hartup, S. Jaffer, S. Keshav, M. Lam, A. Madhavapeddy, R. Message, E.-P. Rau, T. Swinfield and C. Wheeler

About this document

Communicating Methodologies II



6.2 Additionality & Leakage

The calculation of additionality and leakage are very similar and share a core algorithm. In summary, this takes an area of interest (the project or the project's leakage zone) and runs the matching algorithm to find counterfactual pixels for this area. With this set of pairs we then analyse the carbon stock changes in these two regions to make an estimate on the amount of additional carbon (which may be negative in the case of leakage).

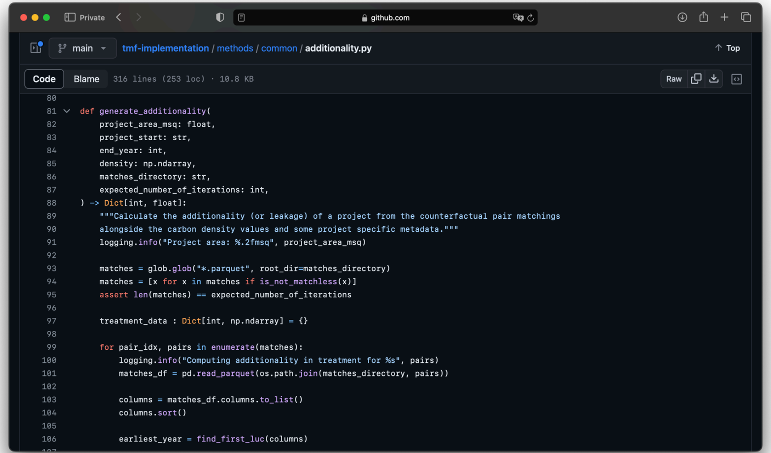
Inputs:

1. Area of Interest (AOI)
2. t_0 the start year and t_{now} the year of assessment (**I1, I2**)
3. The project polygon with leakage buffer (this is explicitly needed as part of the Find Potential Matches section to exclude it from the matching zone, whether calculating additionality or leakage both will remove this entire region). (**I3**)

Algorithm:

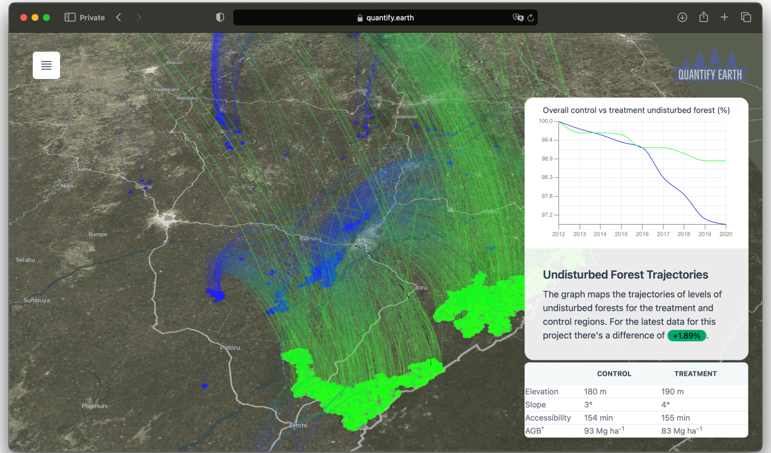
1. Let T be the set of Pixels in the *AOI* at time t_0 (**A24, A25**). Let $|T|$ be the number of pixels in *T.*
2. For each pixel in *T* find its land use class *V.*
3. For each year *t* of time series from t_0 to t_{now}, where t_0 = year of project start and t_{now} is the year of assessment.
   a. Let $N_{T,V}(t)$ be the number of pixels in each class *V* in *T* in year *t*
   b. The proportion of the *AOI* in class *V* in year *t* is $N_{T,V}(t)/|T|$.
   c. For each land use class *V*
      i. Find the total area in class *V* by multiplying $N_{T,V}(t)/|T|$ by the total *AOI* area in ha.
      ii. $S_{T,V}(t)$ = Carbon stock per ha in class *V* * total area of class *V* in the *AOI*.
   d. $P_{tot}(t)$ = total carbon stock for year *t* in the *AOI* = $\Sigma_V S_{T,V}(t)$
   e. In preparation for finding counterfactuals, call procedure Find Potential Matches to generate the set of potential treatment pixels (K) and potential control pixels (M) with:

Communicating Methodologies III


Private
github.com
main
tmf-implementation / methods / common / additionality.py
Top
Code
Blame
316 lines (253 loc) · 10.8 KB
Raw

```python

def generate_additionality(
    project_area_msq: float,
    project_start: str,
    end_year: int,
    density: np.ndarray,
    matches_directory: str,
    expected_number_of_iterations: int,
) -> Dict[int, float]:
    """Calculate the additionality (or leakage) of a project from the counterfactual pair matchings
    alongside the carbon density values and some project specific metadata."""
    logging.info("Project area: %.2fmsq", project_area_msq)

    matches = glob.glob("*.parquet", root_dir=matches_directory)
    matches = [x for x in matches if is_not_matchless(x)]
    assert len(matches) == expected_number_of_iterations

    treatment_data : Dict[int, np.ndarray] = {}

    for pair_idx, pairs in enumerate(matches):
        logging.info("Computing additionality in treatment for %s", pairs)
        matches_df = pd.read_parquet(os.path.join(matches_directory, pairs))

        columns = matches_df.columns.to_list()
        columns.sort()

        earliest_year = find_first_luc(columns)
```

Communicating Methodologies IV



Undisturbed Forest Trajectories

The graph maps the trajectories of levels of undisturbed forests for the treatment and control regions. For the latest data for this project there's a difference of +1.89%.

	CONTROL	TREATMENT
Elevation	180 m	190 m
Slope	3°	4°
Accessibility	154 min	155 min
AGB*	93 Mg ha^{-1}	83 Mg ha^{-1}

Reflections

Code and Science

> *...no-one with the same casual attitude to experimental instrumentation as many researchers have to code would be allowed anywhere near a lab.*

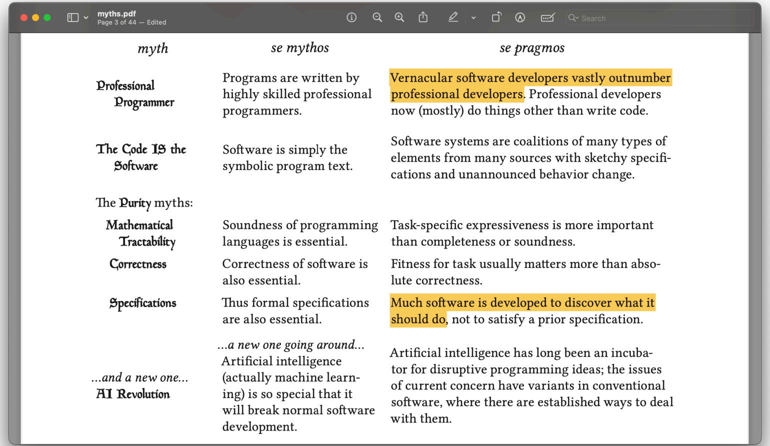
— Baxter et al. [3]

Interdisciplinary vs. Working Relationship

> ***Researcher-Developer*** *wants to be judged on their scientific output, is a researcher at heart, however develops a lot of code due to the nature of their research…*
>
> ***Research Software Engineer*** *comes from a research background but is also a skilled software developer… They want to be recognised for producing tools which others rely on for research.*

— Baxter et al. [3]

Specification vs. Credentials



myth	*se mythos*	*se pragmos*
Professional Programmer	Programs are written by highly skilled professional programmers.	Vernacular software developers vastly outnumber professional developers. Professional developers now (mostly) do things other than write code.
The Code IS the Software	Software is simply the symbolic program text.	Software systems are coalitions of many types of elements from many sources with sketchy specifications and unannounced behavior change.
The Purity myths:		
Mathematical Tractability	Soundness of programming languages is essential.	Task-specific expressiveness is more important than completeness or soundness.
Correctness	Correctness of software is also essential.	Fitness for task usually matters more than absolute correctness.
Specifications	Thus formal specifications are also essential.	Much software is developed to discover what it should do, not to satisfy a prior specification.
...and a new one... AI Revolution	*...a new one going around...* Artificial intelligence (actually machine learning) is so special that it will break normal software development.	Artificial intelligence has long been an incubator for disruptive programming ideas; the issues of current concern have variants in conventional software, where there are established ways to deal with them.

Figure 6: Six myths from Mary Shaw on software, developers and programming languages [5].

Thank you

- Prof. Anil Madhavapeddy and Prof. Srinivasan Keshav
- Colleagues in Plant Sciences and Zoology especially Dr. Tom Swinfield
- Colleagues in Computer Science especially Michael Dales, Derek Sorensen, Ryan Gibb, and Madeline Lisaius

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