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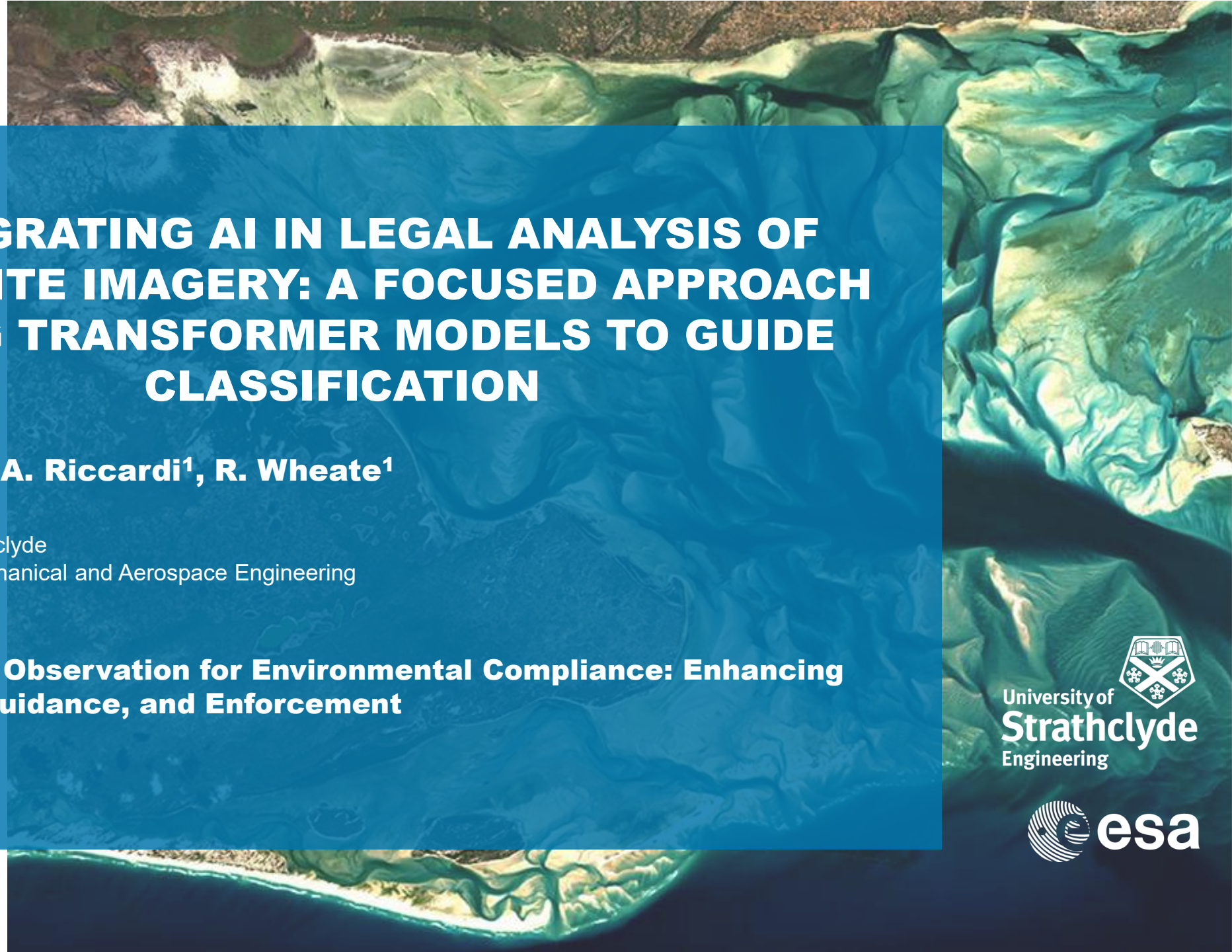

INTEGRATING AI IN LEGAL ANALYSIS OF SATELLITE IMAGERY: A FOCUSED APPROACH USING TRANSFORMER MODELS TO GUIDE CLASSIFICATION

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F.04.11 Earth Observation for Environmental Compliance: Enhancing Monitoring, Guidance, and Enforcement

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Remote Sensing in Criminal and Human Rights Courts

- Humanitarian applications: Documenting war crimes, human rights violations, environmental crimes & boundary disputes
- Subject application is varied
- **Main methods:**
  - Multi-temporal change detection
  - Multispectral analysis (single bands, indices)
  - Non-imagery cross-referencing
- Investigations v. court proceedings (admissibility & acceptability)
  - Well tested & 'relevant' processes (**manual object detection & scene classification)**
  - Time intensive
  - Human errors
  - More complex environments

Table 3
Subject of EO surveillance in court cases.

Subject	Specific detail	Cases
Geophysical features	Water • River morphology • Ocean turbidity • Algae blooms • Sedimentation build-up • Erosion • Chlorophyll	*Prosecutor v. Mahamat Said Abdel Kani* (ICC), *Costa Rica v. Nicaragua (Construction of a Road in Costa Rica along the San Jun River)* (ICJ), *Costa Rica v. Nicaragua (Costa Rica vs Nicaragua - Certain Activities Carried Out by Nicaragua in Border Area)* (ICJ), *Argentina v. Uruguay* (ICJ), *European Commission v. United Kingdom (Portgual Intervening)* (ECJ)
	Vegetation • Vegetation • Forests • Agricultural land	*Sargsyan v. Azerbaijan* (ECtHR), *Prosecutor v. William Samoei Ruto and Joshua Arap Sang* (ICC), *Costa Rica v. Nicaragua (Costa Rica vs Nicaragua - Certain Activities Carried Out by Nicaragua in Border Area)* (ICJ), *Democratic Republic of the Congo v. Uganda* (ICJ), *Armed Activities on the Territory of the Congo (Democratic Republic of the Congo v. Uganda)*, *The Punta Piedra Garifuna community and its members v. Honduras* (IACHR), *Saramaka People v. Suriname* (IACHR), *Sawhoyamaxa Indigenous Community v. Paraguay* (IACHR), *The Indigenous Communities Of The Lhaka Honhat (Our Land) Association V. Argentina* (IACHR)
Infrastructure	Civilian infrastructure • Residential buildings • Mausoleums • Cemeteries • Sites of faith • Stadiums and theatres	*Prosecutor v. Bosco Ntaganda* (ICC), *Prosecutor v. Al Hassan Ag Abdoul Aziz Ag Mohamed Ag Mahmoud* (ICC), *Prosecutor v. William Samoei Ruto and Joshua Arap Sang* (ICC), *Prosecutor v. Germain Katanga and Mathieu Ngudjolo Chui* (ICC), *Prosecutor v. Bahar Idriss Abu Garda* (ICC), *Situation in Georgia* (ICC), *Prosecutor v. Ahmad Al Faqi Al Mahdi* (ICC), *Prosecutor v. Francis Kirimi Muthaura and Uhuru Mugai Kenyatta* (ICC), *Prosecutor v. Ali Muhammah Ali Abd-Al-Rahman ("Ali Kushayb")* (ICC), *Prosecutor v. Alfred Yekatom and Patrice-Edouard Ngaïssona* (ICC), *Situation in the People's Republic of Bangladesh/ Republic of the Union of Myanmar* (ICC), *Prosecutor v. Maxime Jeoffroy Eli Mokom Gawaka* (ICC), *Prosecutor v. Théoneste Bagosora, Gratien Kabiligi, Aloys Ntabakuze, Anatole Nsengiyumva* (ICTR), *Georgia v. Russian Federation* (ICJ), *Bosnia and Herzegovina v. Serbia and Montenegro* (ICJ), *Ukraine v. Russian Federation: 32 States Intervening* (ICJ), *South Africa v. Israel* (ICJ), *Sargsyan v. Azerbaijan* (EHCR), *Eritrea-Ethiopia* (PCA), *The Kichwa Indigenous People of Sarayaku v. Ecuador* (IACHR), *The Punta Piedra Garifuna community and its members v. Honduras* (IACHR), *Mohammed Abdullah Saleh Al-Asad v. the Republic of Djibouti* (ACHPR), *Prosecutor v. Kaing Guek Eav alias Duch* (ECCC)
	Temporary sites • Internal-displaced accommodation • refugee accommodation • Military stations	*Prosecutor v. Bahar Idriss Abu Garda* (ICC), *Prosecutor v. Abdallah Banda Abakaer Nourain*, *Prosecutor v. Francis Kirimi Muthaura and Uhuru Mugai Kenyatta* (ICC), *Prosecutor v. Ali Muhammad Ali Abd-Al-Rahman ("Ali Kushayb")* (ICC), *Prosecutor v. Alfred Yekatom and Patrice-Edouard Ngaïssona* (ICC), *Bosnia and Herzegovina v. Serbia and Montenegro* (ICJ), *Sufi and Elmi v. the United Kingdom* (ECHR), *Chowdury and Others v. Greece* (ECtHR)
	Humanitarian • Internally-displaced people (IDP)/refugee accommodation, e.g. tents, temporary buildings • Peacekeeping sites	*Prosecutor v. Francis Kirimi Muthaura and Uhuru Mugai Kenyatta*(ICC), *Prosecutor v. Bahar Idriss Abu Garda* (ICC), *Prosecutor v. Abdallah Banda Abakaer Nourain*, *Prosecutor v. Alfred Yekatom and Patrice-Edouard Ngaïssona* (ICC), *Bosnia and Herzegovina v. Serbia and Montenegro* (ICJ), *Sufi and Elmi v. the United Kingdom* (ECtHR)
	Military • Trenches • Revetments • Military buildings • Prisons	*Prosecutor v. Ali Muhammad Ali Abd-Al-Rahman ("Ali Kushayb")* (ICC), *Prosecutor v. Abdallah Banda Abakaer Nourain* (ICC), *Prosecutor v. William Samoei Ruto and Joshua Arap Sang*, *Prosecutor v. Alfred Yekatom and Patrice-Edouard Ngaïssona* (ICC), *Sargsyan v Azerbaijan* (ECtHR), *MH17 Plane Crash* (NPPS), *Prosecutor v. Kaing Guek Eav alias Duch* (ECCC)
	Transportation • Roads • Vehicles • Roadblocks • Bridge • Crossings	*Prosecutor v. Francis Kirimi Muthaura and Uhuru Mugai Kenyatta* (ICC), *Prosecutor v. William Samoei Ruto and Joshua Arap Sang* (ICC), *Prosecutor v. Alfred Yekatom and Patrice-Edouard Ngaïssona* (ICC), *Prosecutor v. Théoneste Bagosora, Gratien Kabiligi, Aloys Ntabakuze, Anatole Nsengiyumva* (ICTR), *Sargsyan v Azerbaijan* (ECHR), *Costa Rica v. Nicaragua (Construction of a road)* (ICJ), *Prosecutor v. Charles Ghankay Taylor* (SCSL), *South Africa v. Israel* (ICJ)
Artillery	Launch location Evidence of attack • Craters • Shelling	*Georgia v. Russian Federation* (ICJ), *Prosecutor v. Kaing Guek Eav alias Duch* (ECCC)
Population	Movement	*Prosecutor v. Francis Kirimi Muthaura and Uhuru Mugai Kenyatta* (ICC), *Prosecutor v. Ali Muhammad Ali Abd-Al-Rahman ("Ali Kushayb")* (ICC), *Prosecutor v. Thomas Lubanga Dyilo* (ICC), *Sufi and Elmi v the United Kingdom* (ECtHR)
	Evidence of killing • Killing location • Burial sites • Mass graves • Bodies	*Prosecutor v. Ali Muhammad Ali Abd-Al-Rahman ("Ali Kushayb")* (ICC), *Prosecutor v. Mahamat Said Abdel Kani* (ICC), *Prosecutor v. Ali Muhammad Ali Abd-Al-Rahman ("Ali Kushayb")* (ICC), *Ukraine v. Russian Federation* (ICJ), *Prosecutor v. Kaing Guek Eav alias Duch* (ECCC)

Rapach et al. (2024)

Artificial Intelligence in Law

Uses of AI

- Generative AI: large volumes of info, legal research, e-discovery
- Case & contract management
- Judicial decision-making assistance
- **Processing & analysis of legal evidence**

Inevitability?

- Ethical concerns
- AI can be a powerful tool if used responsibility, including in law
- Can be used to improve evidence

Legal disputes over deforestation

- Environmental rights embedded in national & international law
- Drive to prosecute offenders (individuals/groups/ organisations/governments)
  - rights held by communities
  - the environment as its own asset

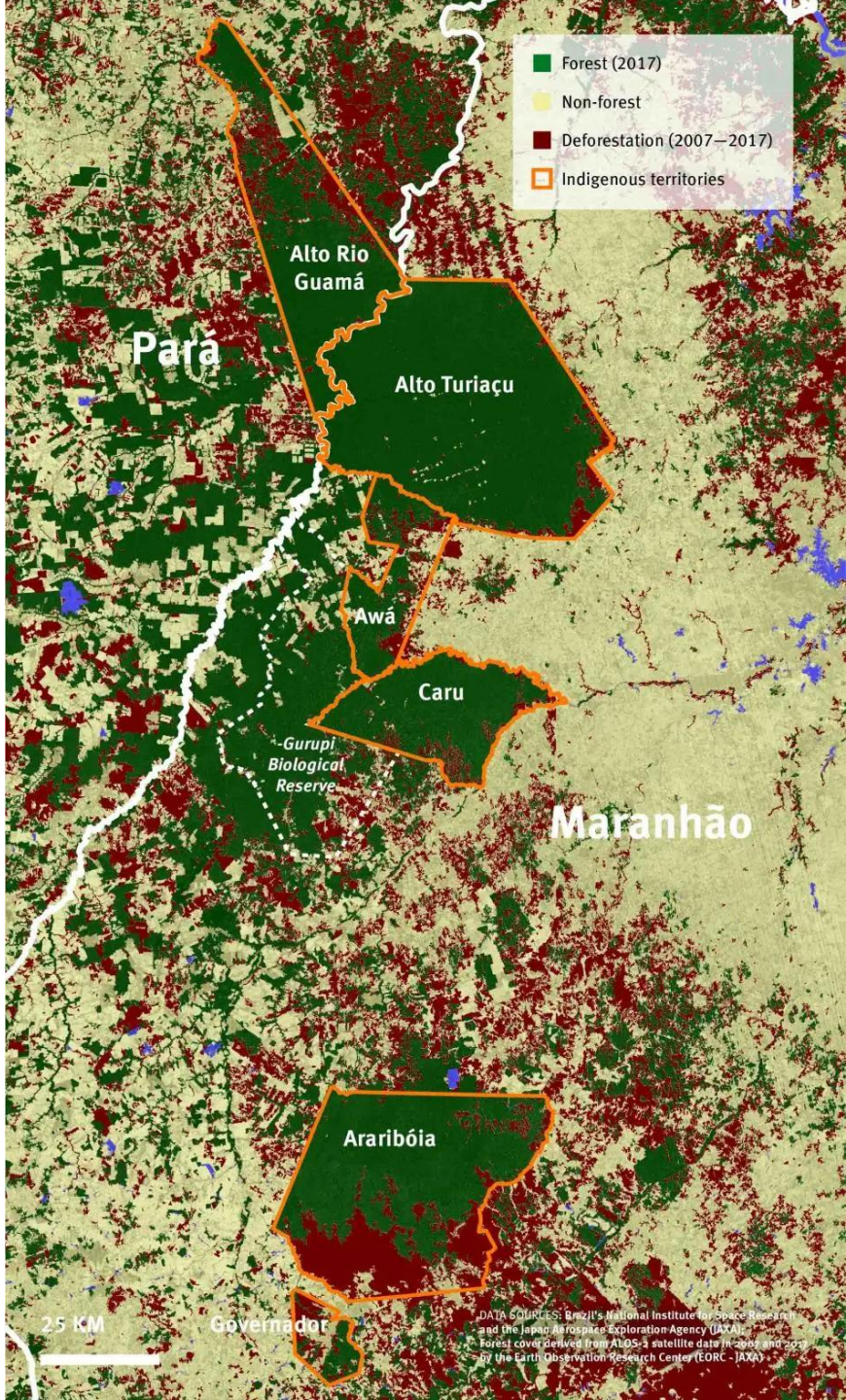
National courts (*e.g. PSB & others v. Brazil* 2020)

- Federal Supreme Court
- Action against Federal Government for violating fundamental rights of indigenous peoples
- 34% increase in the Amazon deforestation

International court (e.g. *Case of the Punta Piedra Garifuna Community and its Members V. Honduras* 2015)

- Inter-American Court of Human Rights
- 'Violating the Right to Property'
- Landcover maps from satellite imagery

Human Rights Watch (2019)



Case Study: Consensus in influencing multi-head attention mechanism

OVERVIEW

- Always a concern over the reliability of scientific evidence presented in court as evidence, such as the prevalence of misclassifications that can mislead the court
- ‘Blackbox’ problem
- Multiheaded transformer models have **attention heads** that learn different unique features, therefore it can manipulated to force predictions a certain way, e.g. more conservative (lenient towards class 0) or more expansive (lenient towards class 1)
- Can help derive what the model is learning
    - Can identify and mitigate discriminatory patterns in models

Case Study: Consensus in influencing multi-head attention mechanism

1. Identify attention heads that have the most influence on the model
2. 'Hot Tub' Method
3. Greater confidence classification

- **Model:** Applied Schiller (2023) SBERT classification model
  - Requirement was to using a pre-trained model
  - Trained and fine-tuned on Sentinel-2 Force datacube across Germany and Luxenberg
  - Withheld Brandenburg labelled dataset and model used for testing the process
- **Attention heads** identify unique patterns across the data
- Selected heads that have the most influence on the model i.e. the most true positive and true negative classifications

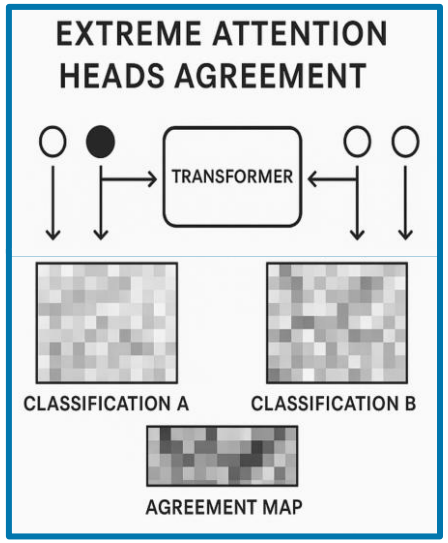
Case Study: Consensus in influencing multi-head attention mechanism

1. Identify attention heads that have the most influence on the model

2. 'Hot Tub' Method

3. Greater confidence classification

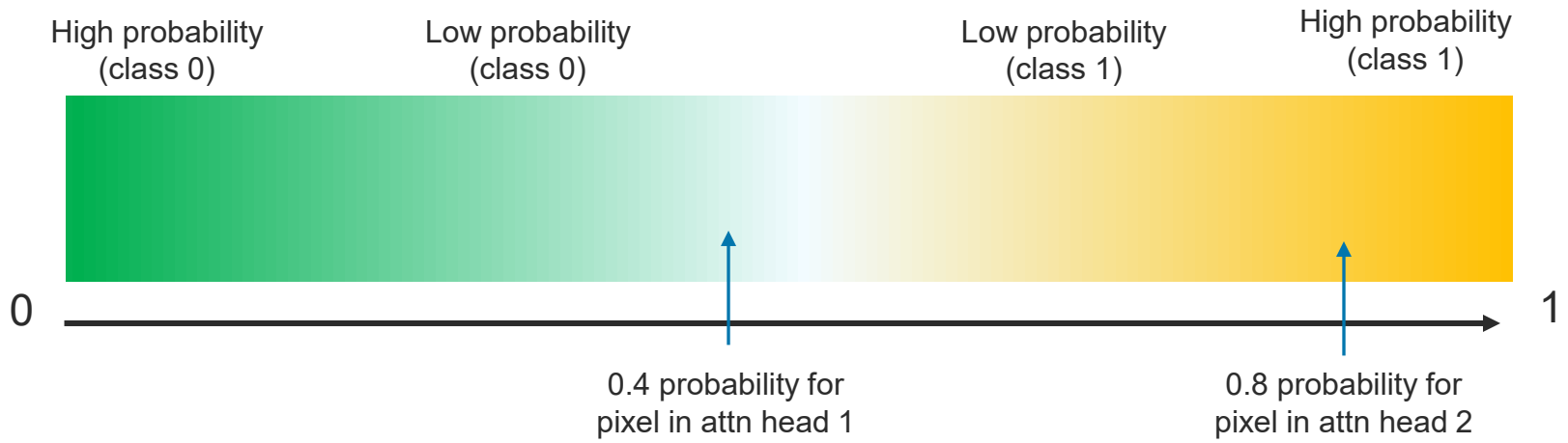
What to find agreement between the two extremes of the model, similar to Concurrent Evidence (or ‘Expert Hot Tubbing’) processes that is used in some national courts, such as in Australia



Case Study: Consensus in influencing multi-head attention mechanism

1. Identify attention heads that have the most influence on the model
2. 'Hot Tub' Method
3. Greater confidence classification

- Each classification has a probability for that classification



- Compute the probability in disputed pixels and assign class that has greater probability

Case Study: Consensus in influencing multi-head attention mechanism

EXTREMES OF MODEL

Attn head 1

True label \ Predicted label	0	1
0	34544	414
1	1455	508

tp/fp: 0.349
tn/fn: 83.439

Attn head 2

True label \ Predicted label	0	1
0	31278	3680
1	1235	728

tp/fp: 0.589
tn/fn: 8.499

Attn head 3

True label \ Predicted label	0	1
0	17086	17872
1	100	1863

tp/fp: 18.630
tn/fn: 0.956

Attn head 4

True label \ Predicted label	0	1
0	25986	8972
1	872	1091

tp/fp: 1.251
tn/fn: 2.896

Attn head 5

True label \ Predicted label	0	1
0	27311	7647
1	728	1235

tp/fp: 1.696
tn/fn: 3.571

Attn head 6

True label \ Predicted label	0	1
0	30779	4179
1	1595	368

tp/fp: 0.231
tn/fn: 7.365

Attn head 7

True label \ Predicted label	0	1
0	33274	1684
1	1151	812

tp/fp: 0.705
tn/fn: 19.759

Attn head 8

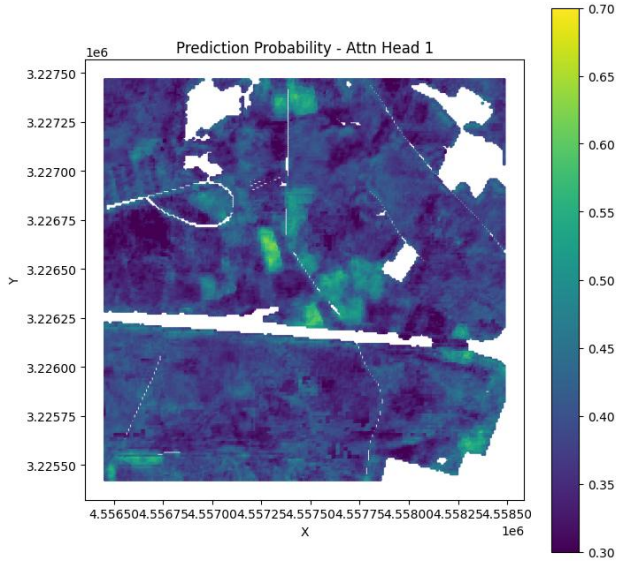
True label \ Predicted label	0	1
0	27972	7031
1	917	1046

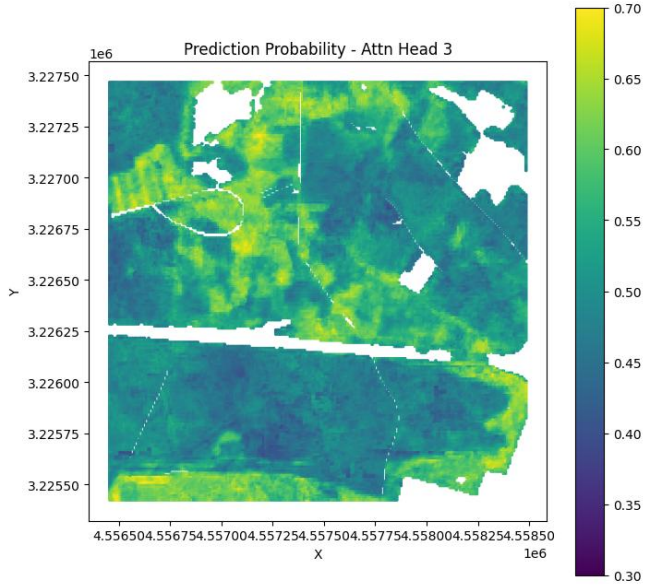
tp/fp: 1.407
tn/fn: 3.971

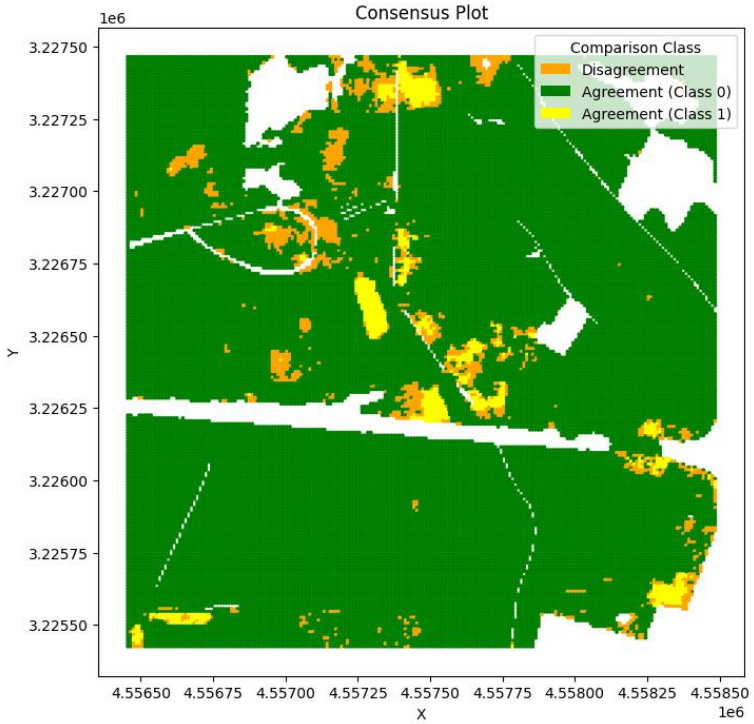
Case Study: Consensus in influencing multi-head attention mechanism

‘HOT TUB’ Method

Overlap the extreme classification maps to output a consensus map







Case Study: Consensus in influencing multi-head attention mechanism

GREATER CONFIDENCE

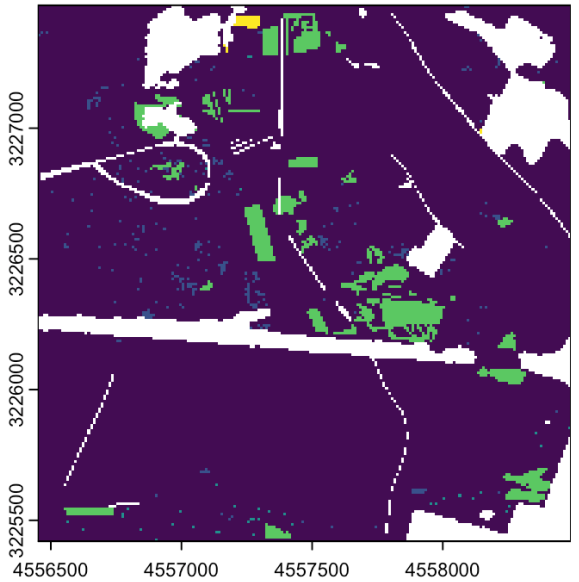
- Each prediction has a probability to its classification
  - Greater deviation from 0.5 = greater confidence

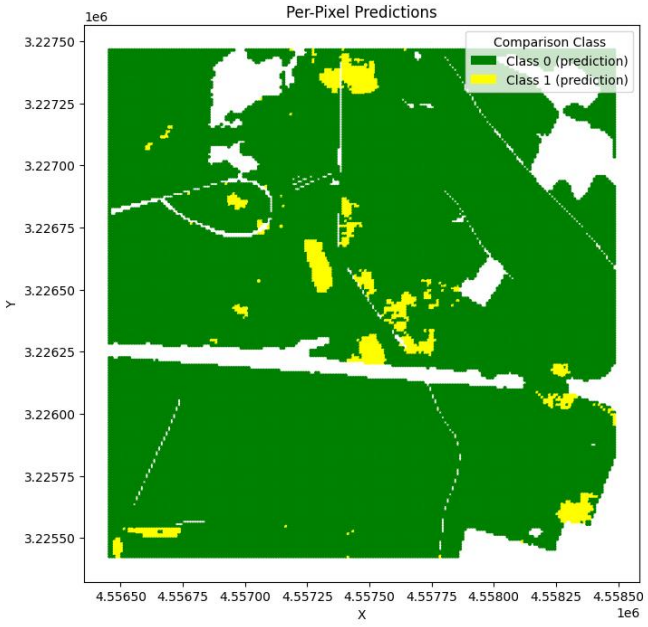
- Assessed the confidence in the pixel classification where they are in disagreement and reclassified to class with stronger probability

- Balanced the misclassifications
- FP/FN = 0.51

- Improvement in correct prediction of class 0

Classes	Precision	Recall	F1-score
Undisturbed (class 0)	0.96	0.98	0.97
Disturbed (class 1)	0.51	0.32	0.39





FURTHER STEPS

There are many factors that determine the admissibility and relevance of evidence. The model in question could assist in delivering useful information, but other factors will also need to be considered in future work:

- Accuracy of the model
  - E.g. **Imbalance** between two classes (in use case)
  - Variety of training data – Temporal and spatial
- Testing other parameters of the model that require investigation of consensus

Thank you for listening

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