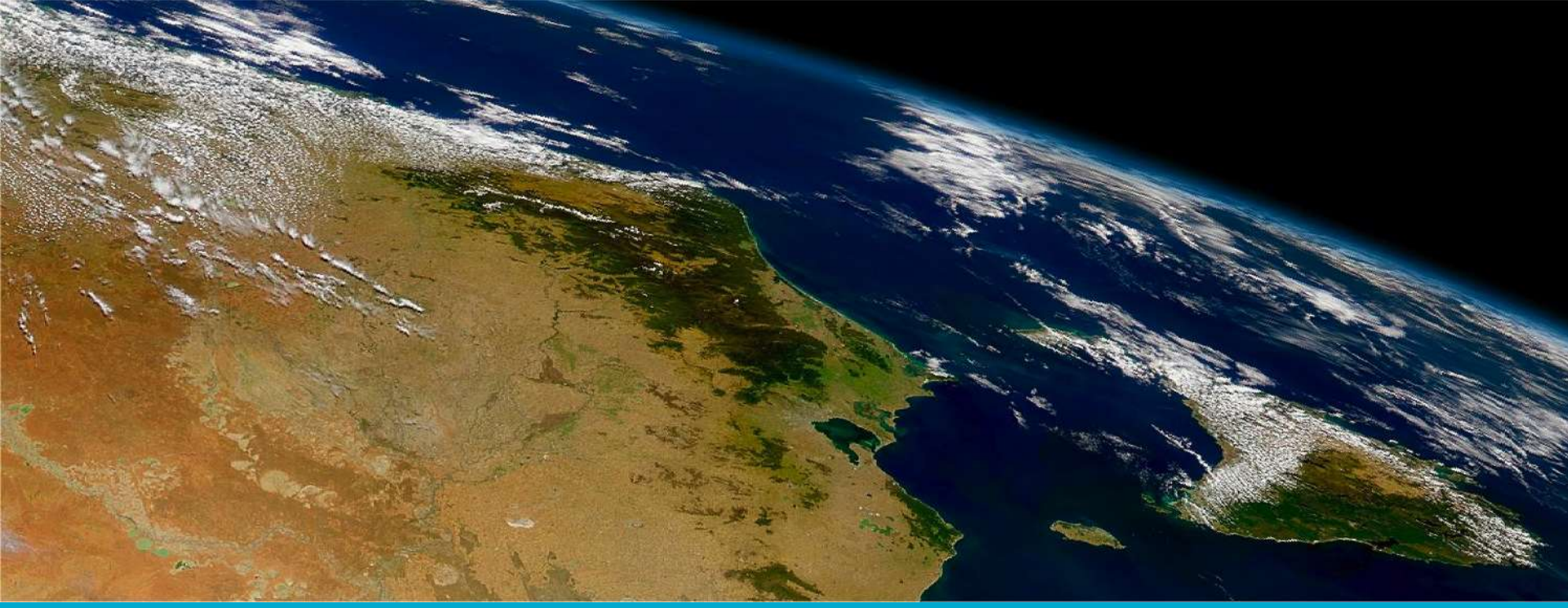


Inferring the Unobservable

Diagnosing ecosystem processes of water & carbon exchange in landscapes

Prof Damian Barrett

26 June 2012

WATER FOR A HEALTHY COUNTRY FLAGSHIP
www.csiro.au

TERN Terrestrial Ecosystem Research Network

Australian Government
Australian Research Council

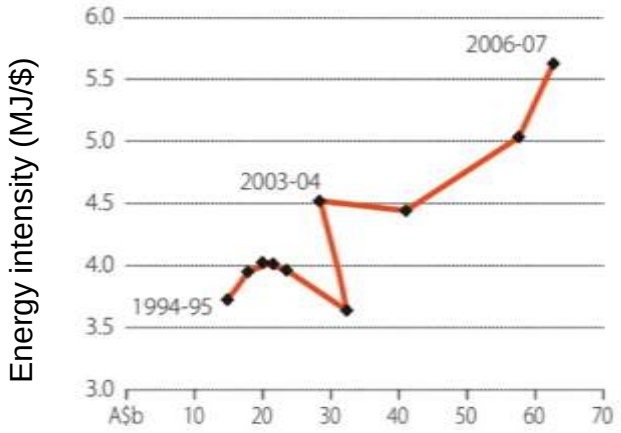
ACARP

The University Of Queensland
AUSTRALIA

SMI Sustainable Minerals Institute

CSIRO

Global change



Mining export revenue (AUD$b)

Extensive global human impacts on land, water and atmospheric systems are ongoing and well documented

Intensive global human impacts are also accelerating

Australian mining industry

- 7% energy consumed → +13% (2030)
- 508 GL p.a. (2008/9) →1000 GL (2020)
- 62 GL p.a. water use (energy)
- +107 GL p.a. water use (energy) (2020)

Acquisition of water and land resources for mining extends well beyond the boundaries of mining lease

Less well known are effects of intensive drivers on extensive landscape processes

Global change

Extensive LUC grazing since 1960's

Intensive LUC mining expansion (1970's)

Mining interacts with surrounding landscape carbon & water cycles and extends footprint into surrounding catchments & regions

20C: Extensive drivers → Extensive LUC

21C: Intensive drivers → Extensive LUC

Example: Access to land for environmental offsets

Miners scout rural land for environmental offsets

Matthew Cranston

Big mining companies are scrambling to secure conservation land in Queensland to offset the environmental impact of their mining projects under federal and state laws.

Rio Tinto has just snapped up four rural land holdings valued at more than $10 million near Clermont in central Queensland for offsets.

Indian conglomerate GVK and Hancock Coal have earmarked seven properties for purchase, BHP Billiton Mitsubishi Alliance has four rural properties ready to be used for offsets, and Xstrata is looking for rural holdings to offset its environmental impact as well.

The offset property must be land that is not subject to any future development of any kind, whether agricultural or mining related – but that increases the difficulty of finding suitably available land.

Up to 90 per cent of Queensland's land comes under the title of "exploration permit for coal", leaving little available for offsets.

Some miners have had to decide whether they forgo mining development on other land they own in order to reserve it for environmental offsets. Some are even prepared to pay a premium to buy land.

Elders rural agent Lloyd Hansen said there was already a danger that the miners were buying up land and not properly controlling it.

"Many of them have just bought it and locked it up, and now all the trees and weeds are growing back and they have got wild pigs," Mr Hansen said. "It's becoming a disaster."

Some players are taking a new approach, asking farmers to sign up to agreements where the miner pays the farmer to improve parts of his own land and meet the environmental offset requirements.

Pioneering the offset industry is Earthtrade managing director Alan Key. "There is not a huge amount of land that fulfils the requirements," he said. "Trying to locate it where it won't be developed in the future is difficult."

Mr Key said an agreement with farmers was a good initiative but also carried some dilemmas. "I don't want to scare people in saying these agreements are too hard but they are complex," he said. "They take some time to get done."

Australian Financial Review 18/6/2012

A policy tool: "*…conservation actions intended to compensate for the residual, unavoidable harm to biodiversity caused by development projects so as to ensure no net loss of biodiversity*" (ten Kate et al. 2004)

Current policy requires 4:1 – 20:1 ratio of offsets increasing competition for land & potentially displacing agriculture

Managing risks/opportunities of offsets requires improved biophysical understanding how intensive drivers impact on regional carbon/water cycles

Biophysical processes at landscape scale are not directly observable

(particularly in data sparse regions)

They can be 'observed' (in an inverse sense) by conditioning model states or parameters using observations

Diagnosing biophysical processes

'Traditional' modelling: $M(\mathbf{y}, \mathbf{p}) \rightarrow \mathbf{x}$

'Inverse' modelling: $H(\mathbf{x}, \mathbf{p}) = M^{-1}(\mathbf{x}, \mathbf{p}) \rightarrow \hat{\mathbf{y}}$

- H: 'Observation operator' & can be complex with coupled models
- MDA methods allow conditioning of states/parameters with real observations

$$Min\ J = \left(\mathbf{y} - H(\mathbf{x}_a, \mathbf{p})\right)\mathbf{R}^{-1}\left(\mathbf{y} - H(\mathbf{x}_a, \mathbf{p})\right) + \left(\mathbf{x}_a - \mathbf{x}_b\right)\mathbf{B}^{-1}\left(\mathbf{x}_a - \mathbf{x}_b\right)$$

R = covariance matrix of observation errors
B = covariance matrix of model errors
p = parameters
$\mathbf{x}_a$ = analysis state vector
$\mathbf{x}_b$ = 'background' vector of model states

- However, finding the $Min\ J$ is 'expensive' (large problems)
- Requires re-evaluation of H every iteration of a search algorithm

3D-VAR assimilation

$$Min\ J = \left(\mathbf{y} - H\left(\mathbf{x}_a, \mathbf{p}\right)\right)\mathbf{R}^{-1}\left(\mathbf{y} - H\left(\mathbf{x}_a, \mathbf{p}\right)\right) + \left(\mathbf{x}_a - \mathbf{x}_b\right)\mathbf{B}^{-1}\left(\mathbf{x}_a - \mathbf{x}_b\right)$$

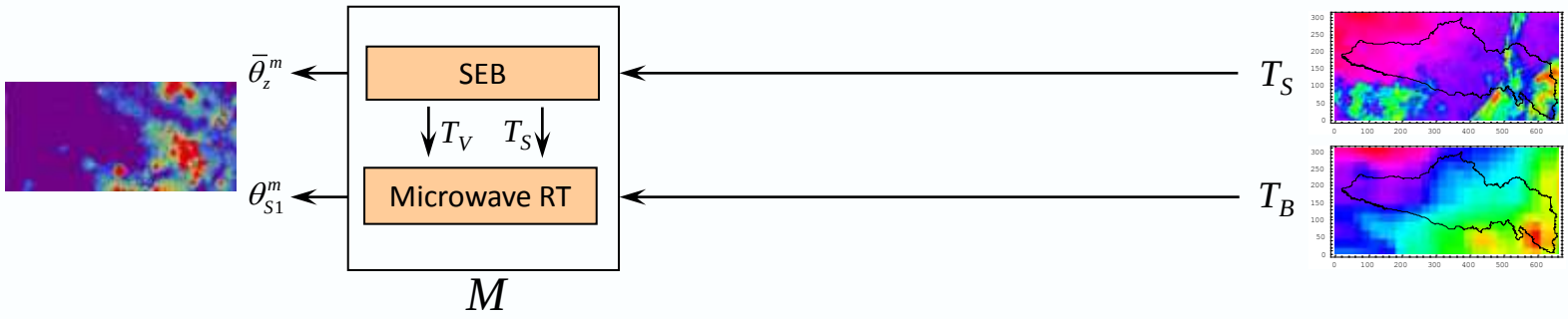
Taylor expansion of observation model

$$Min\ J = \left(\mathbf{y} - \overbrace{H\left(\mathbf{x}_b, \mathbf{p}\right) - \mathbf{H}\left(\mathbf{x}_a - \mathbf{x}_b\right)}\right)\mathbf{R}^{-1}\left(\mathbf{y} - H\left(\mathbf{x}_b, \mathbf{p}\right) - \mathbf{H}\left(\mathbf{x}_a - \mathbf{x}_b\right)\right) + \left(\mathbf{x}_a - \mathbf{x}_b\right)\mathbf{B}^{-1}\left(\mathbf{x}_a - \mathbf{x}_b\right)$$

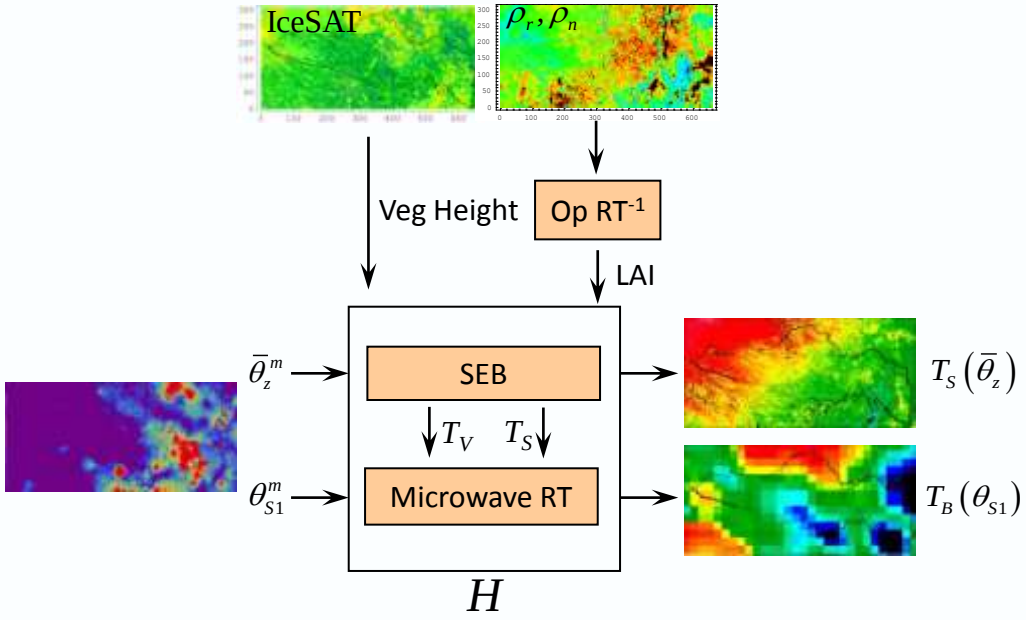
$$\mathbf{H} = \begin{bmatrix} \left.\frac{\partial H}{\partial p_1}\right|_{p_1} & \left.\frac{\partial H}{\partial p_2}\right|_{p_1} & \cdots \\ \left.\frac{\partial H}{\partial p_1}\right|_{p2} & \left.\frac{\partial H}{\partial p_2}\right|_{p2} & \cdots \\ \vdots & \vdots & \ddots \end{bmatrix}$$

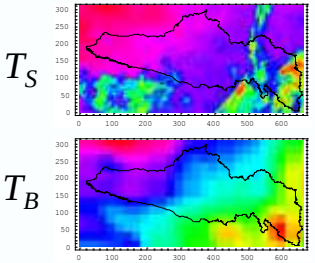
- **H** is the ‘tangent linear operator’: sensitivity of model to states/parameters
- Requires evaluation of H and construction of **H** once only
- **H** quantifies conditions under which observations maximally inform model

Assimilating remote sensing observations



Assimilating remote sensing observations





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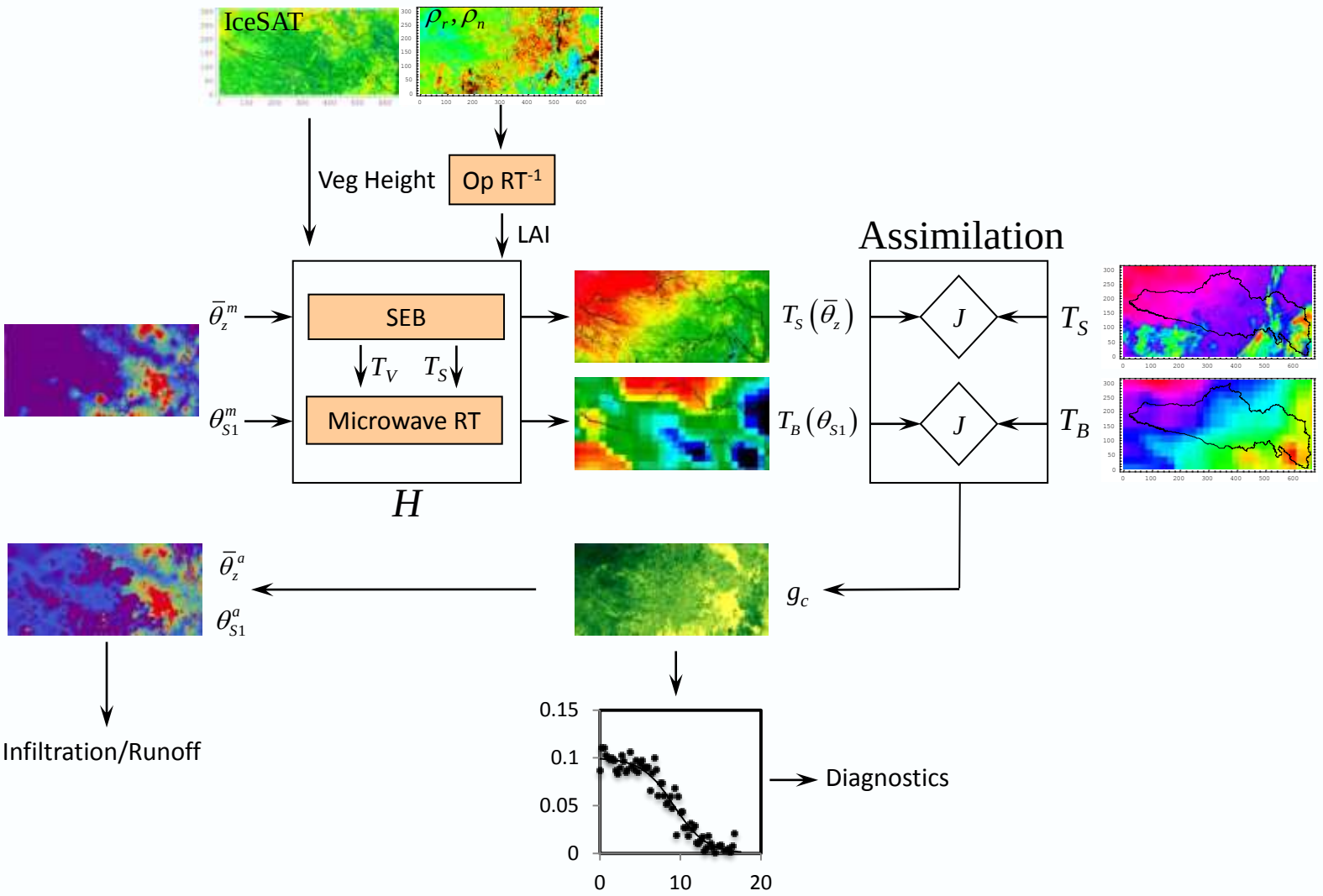
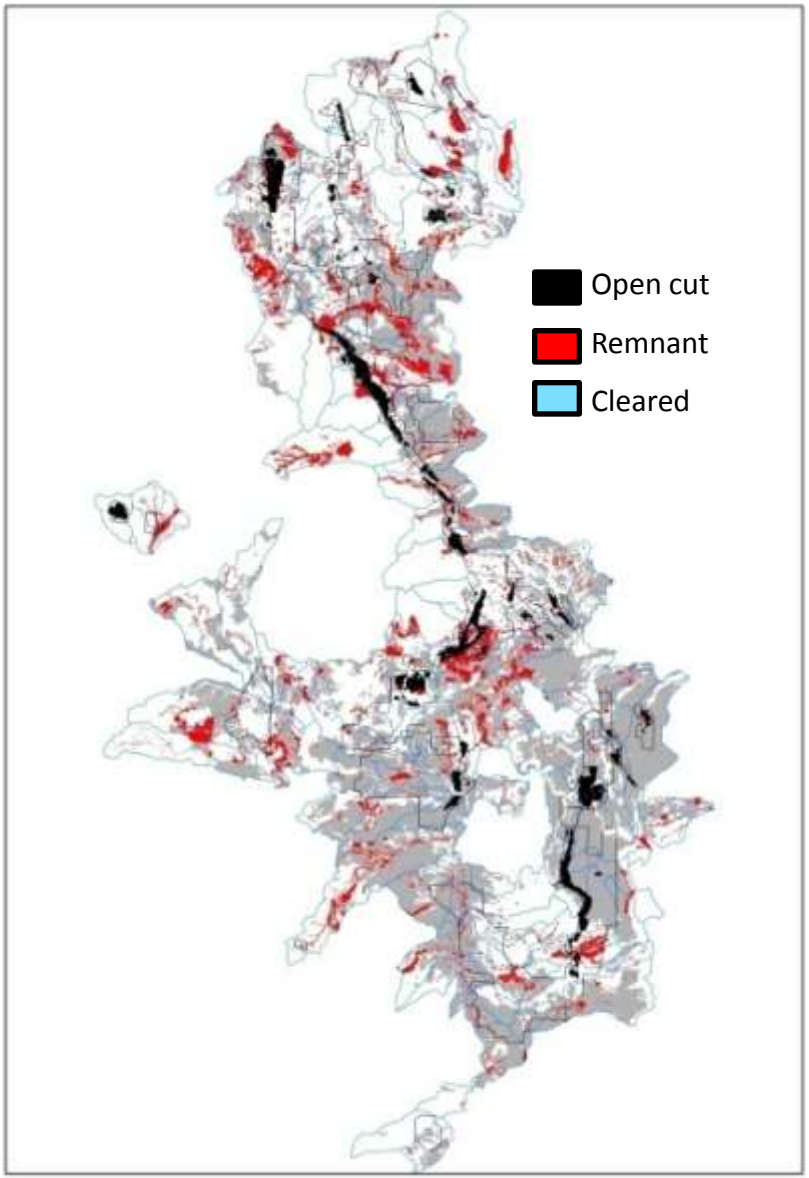


Carbon & water impacts of environmental offsets



- Fitzroy: extensive LUC (6Mha)
  - 40% native woodland remains
  - 10% remains on clay soils
  - Brigalow woodlands 96% cleared

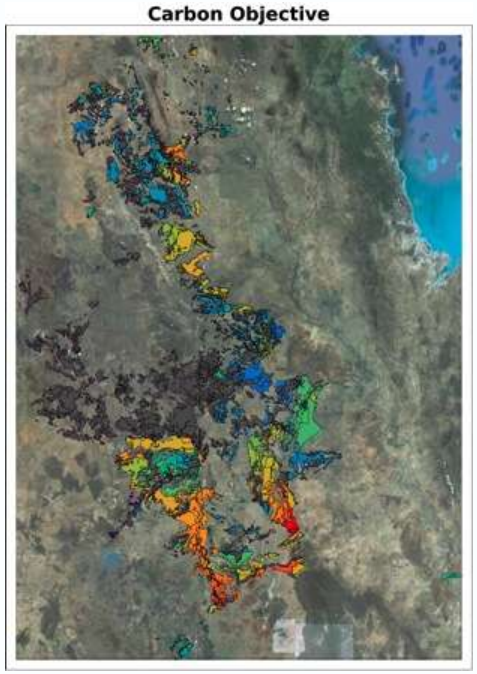
- Isaacs – Mackenzie Rs.

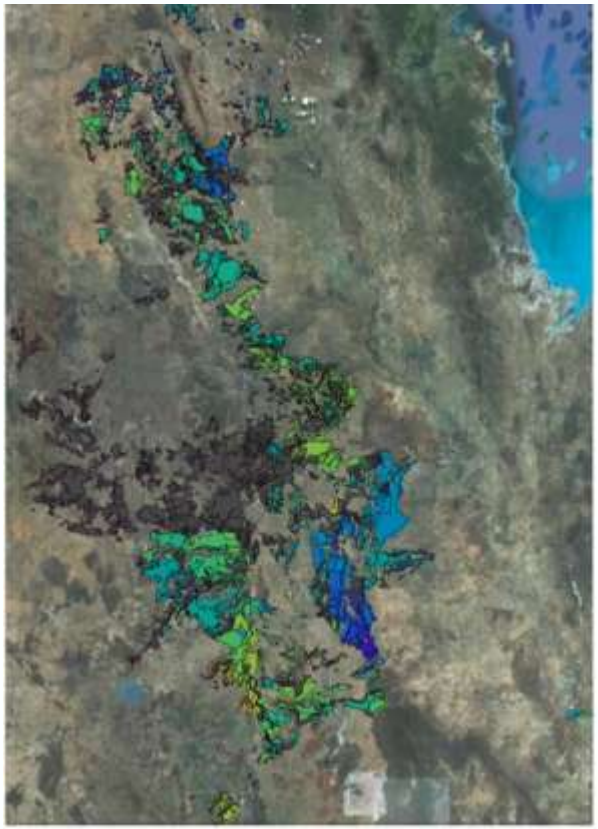
- How do we minimise the impacts of revegetation on runoff to rivers while maximising carbon storage?

Spatial optimisation of carbon & water impacts

Reduction in runoff

Increment carbon





partial objectives

weighted objective

Summary

21C: Increasing impacts of intensive drivers on extensive land use change

Environmental offsets for land, water and carbon will impact on ecosystem carbon and water cycles

MDA tools diagnose landscape scale states and parameters from remote sensing data

Provides a comprehensive and rigorous scientific basis for sound management and planning decisions around environmental offsets

- Potential of environmental offsets to alleviate extensive impacts
- Tools for decision making, manage risks & cost – benefits analysis
- Ensure establishment of offsets is integrated into regional ecology

Thank you

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