Measuring Natural Capital on Agricultural Farm

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What is Natural Capital?

- Stock of natural assets that provides natural resource inputs and environmental services for economic production.

- **Components of natural capital**:

  (a) non-renewable resources – e.g., minerals and fuels

  (b) renewable resources – e.g., water, soil, forest and vegetation

  (c) environmental/ecosystem services – e.g., air and water filtration, pollinations for crops, habitat for fisheries and wildlife

Why natural capital accounting (NCA)?

Inadequate information on natural capital → Poor management decision on farm practices → Unsustainable use of natural capital → Long-term lower productivity of farm

Rich information on natural capital → Improved management decision on farm practices → Sustainable use of natural capital → Long-term higher productivity of farm

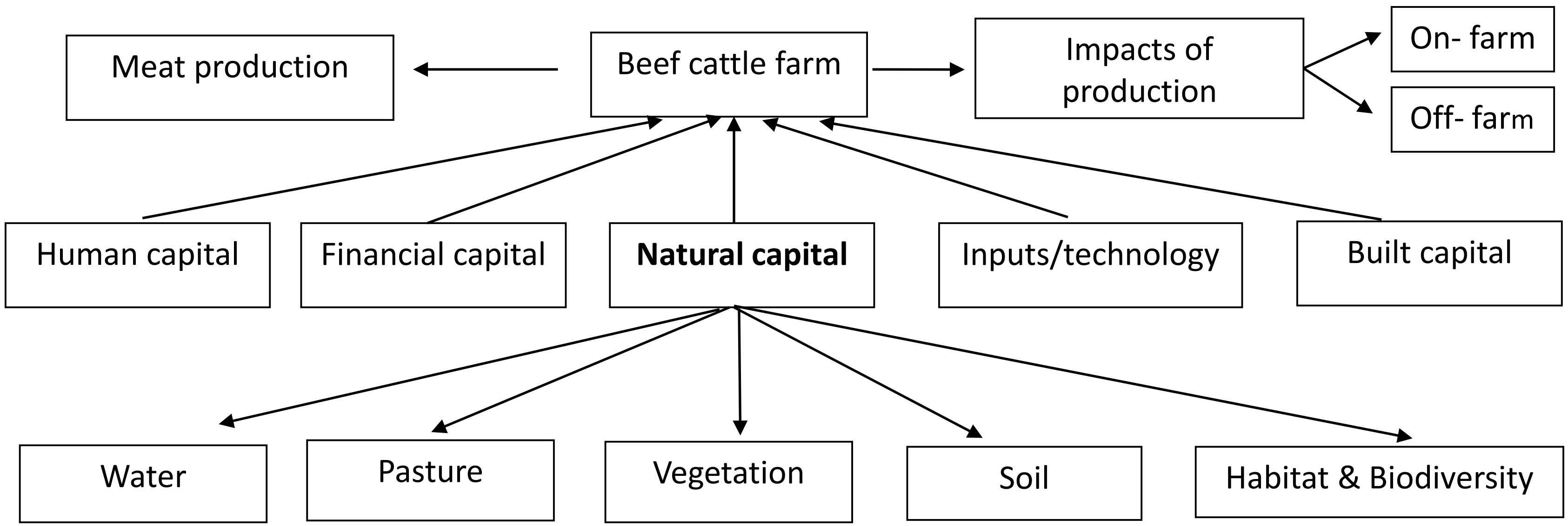
Necessity of NAC: if we can't measure it, we can't manage it.

Stocks and Flows of Benefits of Natural Capital

Stocks	***Flows of benefits and services***
Soil organic matter/ soil carbon	Soil nutrient, soil fertility
Subsoils	Minerals and fuels
Water resources (fresh, ground water and marine)	Water consumption and water use in agricultural production
Forest and vegetation	Forest timber, fibre resources
Ecosystem assets	Air and water filtration, flood protection, pollinations for crops, habitat for fisheries and wildlife

NCA Model : An example for Beef Cattle Farm

(Stock and Flow benefits)



On-farm impacts: Soil erosion, soil quality deterioration, reduction in soil and vegetation cover

Off-farm impacts: Pollution, rising water table, carbon emission, biodiversity loss

Objectives of the Study

- To account for natural capital in the context of agricultural production processes;
- To assess the impact of agricultural production on the natural resource base and surrounding environment , and how it will affect the change in stock and flows of natural capital;
- To estimate the performance of agricultural farming activities in relation to natural resource use to obtain an indication of how efficiently and sustainably natural capital is being used in the agricultural sector

Table 1. Candidate indicators/variables and attributes for natural capital accounting

Attributes / Candidate indicators	Temporal variability	Spatial variability	Measurability (measurable for management)	Implication for productivity	Management options and (cost)	On/off farm effect
Soil health indictor Soil EC Organic carbon Soil pH	Very slow	High	Easy/complex	High	Many (Low)	On farm
Soil erosion	Slow	Low	Easy	Low	Few (High)	On farm
Soil /land cover	Slow	Low	Easy	Low	Many (Low)	On farm
Water use (surface/ground water)	Depends on climate	Low	Easy	High	Many (low)	On farm
Water table (flow and scarcity)	Depends on climate	High	Easy	High	Scare (High)	Off farm
Water quality	Slow and fast	Low and High	Easy	High	Few (High)	On and off farm
Carbon	Very slow	Low	Complex	Low	Very few (High)	On and off farm
Vegetation (on farm)	Slow	Low	Easy	Low	Many (Low)	On farm
Biodiversity	Very slow	Low	Complex	Low	Many (Low)	On and off farm
Energy use (cost/efficiency)	Depends on farm	Depends on farm	Easy	High	Many (Low)	On farm
Pollution	Slow	Low	Complex	Low	Few (High)	On and off farm

Conceptual framework for Measuring Soil Natural Capital

- Luenberger soil-quality indicator (Hailu and Chambers, 2012)
- Static model : variation across space – can be used when comparing soil quality across farms or regions
- Modify the static model to a time variant, dynamic model
- The dynamic model can be used to measure change in soil quality across time.

Conceptual Framework: Soil Natural Capital Indicator

Assume that s = vector of L soil quality attributes
x = vector of N 'usual' production inputs
y = vector of M outputs

Production technology function

$T = \{(s, x, y): (s, x) can\ produce\ y\}$

The production function can be characterised by a directional distance function:

$$D(s, x, y: g_{s,}g_{x,}g_y) = \sup\{\theta: (\Delta s - \theta.\, g_s, x - \theta.\, g_x, y + \theta.\, g_y) \in T, \theta \in \mathcal{R}_+\}$$

Where, $g_s \in \mathcal{R}_+^L$, $g_x \in \mathcal{R}_+^N$, $g_y \in \mathcal{R}_+^M$

To define a soil natural capital indicator, directional vectors for both inputs (g_x) and outputs (g_y) are set to zero:

$$D(s, x, y: g_s) = \sup\{\beta: (\Delta s - \beta.\, g_s, x, y) \in T, \beta \in \mathcal{R}_+\}$$

Conceptual Framework: Soil Natural Capital Indicator

Consider two time variant soil quality vectors s^t and s^{t+1},

Which are vector of changes of soil quality attributes observed on a farm over two time periods, t and t+1

To compare soil vector s^{t+1} against s^t using isoquant I_{s0}^t as the frontier,

the soil quality indicator for a production unit can be constructed as follows:

$$SQ^t(s^t, s^{t+1}, x_0^t, y_0^t; g_s) = D_{s0}^t(s^{t+1}, x_0^t, y_0^t : g_s) - D_{s0}^t(s^t, x_0^t, y_0^t : g_s)$$

This indicator measures the difference between the distances of two soil quality vectors (s^t, s^{t+1}) from the production frontier (isoquant) I_{s0}^t, where the distances are measured in the direction of g_s.

Conceptual Framework: Soil Natural Capital Indicator

If $D_{s0}^{t}(s^{t+1}, x_0^t, y_0^t: g_s) < D_{s0}^{t}(s^{t}, x_0^t, y_0^t: g_s)$,

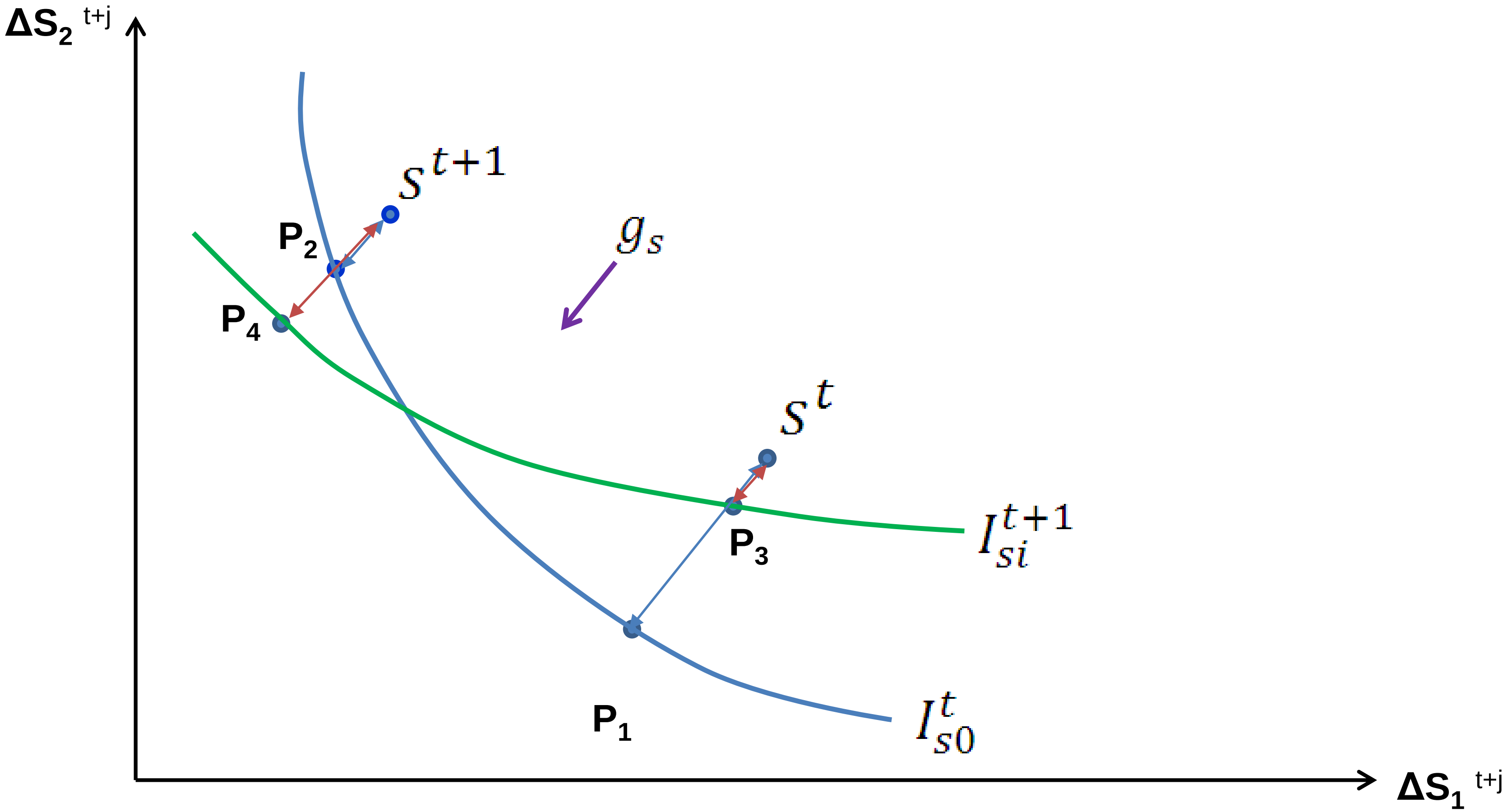
Then s^{t+1} can be treated as improvement in soil quality

Farm has improved its soil natural capital (represented by the soil quality vector) while producing a given level of output y_0^t in conjunction with a variable input usage of x_0^t.

If we want to compare soil quality vector s^{t+1} against s^t using this new frontier I_{si}^{t+1}, then the soil quality indicator can be written as:

$$SQ^{t+1}\left(s^t, s^{t+1}, x_i^{t+1}, y_i^{t+1}; g_s\right)$$
$$= D_{si}^{t+1}\left(s^{t+1}, x_i^{t+1}, y_i^{t+1}: g_s\right) - D_{si}^{t+1}\left(s^{t}, x_i^{t+1}, y_i^{t+1}: g_s\right)$$

Graphical Presentation: Soil Natural Capital Indicator



Conceptual Framework: Soil Natural Capital Indicator

The soil natural capital indicator can be derived based on the average value of two soil quality indicators, $SQ^t(s^t, s^{t+1}, x_0^t, y_0^t; g_s)$ and $SQ^{t+1}\left(s^t, s^{t+1}, x_i^{t+1}, y_i^{t+1}; g_s\right)$ (Hailu and Chambers, 2012).

In this case both isoquant, I_{s0}^t and I_{si}^{t+1} are to be considered as the production frontier.

The soil natural capital indicator:

$$SNCI\left(s^t, x_0^t, y_0^t, s^{t+1}, x_i^{t+1}, y_i^{t+1}; g_s\right) = -\frac{1}{2}[SQ^t(s^t, s^{t+1}, x_0^t, y_0^t; g_s) + SQ^{t+1}\left(s^t, s^{t+1}, x_i^{t+1}, y_i^{t+1}; g_s\right)]$$

Conceptual Framework: Soil Natural Capital Indicator

- This dynamic soil quality indicator can signal whether a farm has improved its soil quality between period *t* and *t+1*.
- If the value of the soil natural capital indicator is zero, there is no change in soil quality between these two periods.
- The positive value of this indicator indicates an improvement in soil quality.
- Soil quality declines if the value of the indicator is less than zero.

Data

Input data	Output data
Pasture (area, growth)	Volume of sale (number of cattle)
Land for fodder crops	Sale price of beef cattle
Soil quality data (soil pH, EC, organic carbon)	
Fertiliser use	Production per hectare (‘total weight of cattle sold’ divided by ‘total land grazed’)
Other purchase inputs	Meat income per grazing hectare (‘proceeds from cattle sold’ divided by ‘total hectare grazed’
On-farm vegetation	
Energy and fuel cost	
On and off-farm impacts	
Numbers of beef cattle bought and purchase prices	

Soil Data Collection Using on-the-go Sensors

Sensor can measure:
pH, Organic carbon, Soil electrical conductivity

Supplier in Australia: CormaGeo Instruments

Conclusions

- Measuring NC on agricultural Farms very challenging
- Complex relationship between stock and flow of NC
- More methods/techniques to measure NC is needed – particularly for quantifying some environmental services (i.e., pollination for crops)
- Non-availability of farm level data