# SOIL SECURITY


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# Reference

McBratney, Field & Koch (2014)
The dimensions of soil security.
*Geoderma* **213**, 203-213.

# Why Soil Security?

- Global Existential Challenges


- The biggest challenge?
- 9 billion+ by 2050
- Soil-limited - space, appropriate soil, degradation

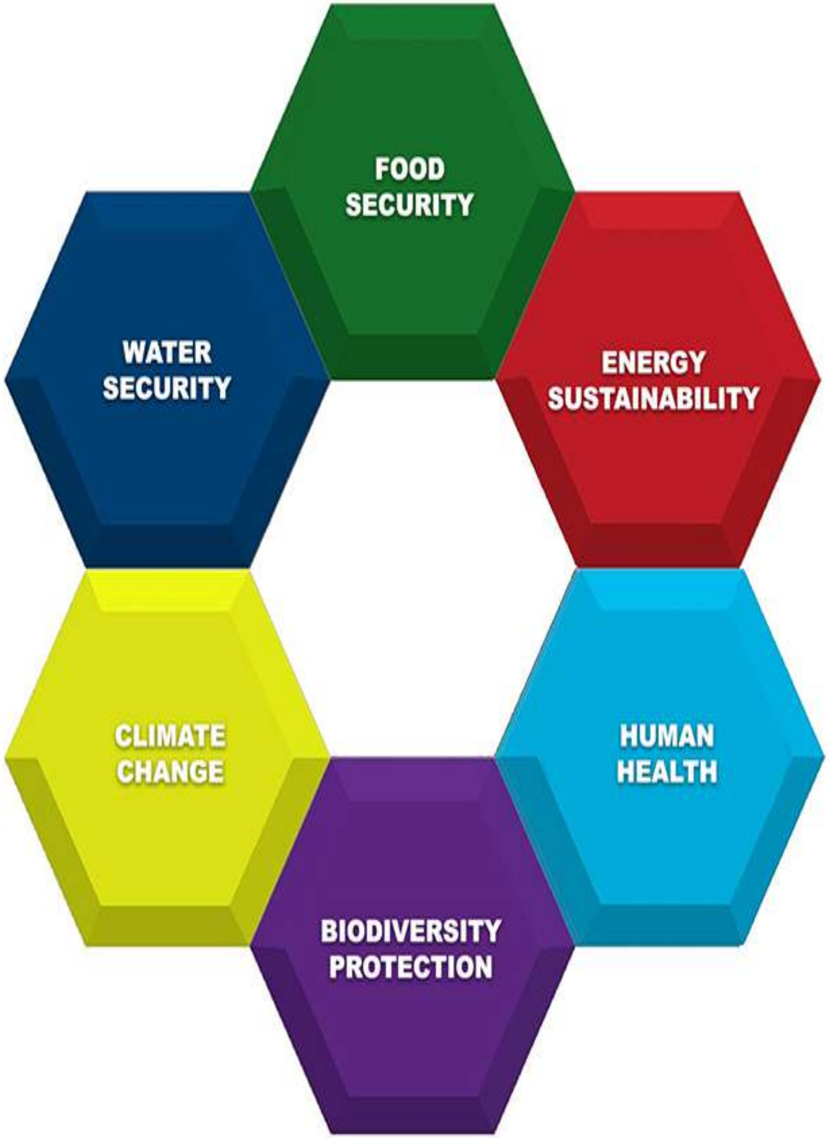

- A fast-growing challenge?
- Agriculture uses ~70% fresh water
- Soil can store (30000 $km^3$) ~2% but much of agricultural use goes through soil


- A fading challenge perhaps?
- Agriculture via soil can produce renewable energy
- Solution of one global challenge can compromise others

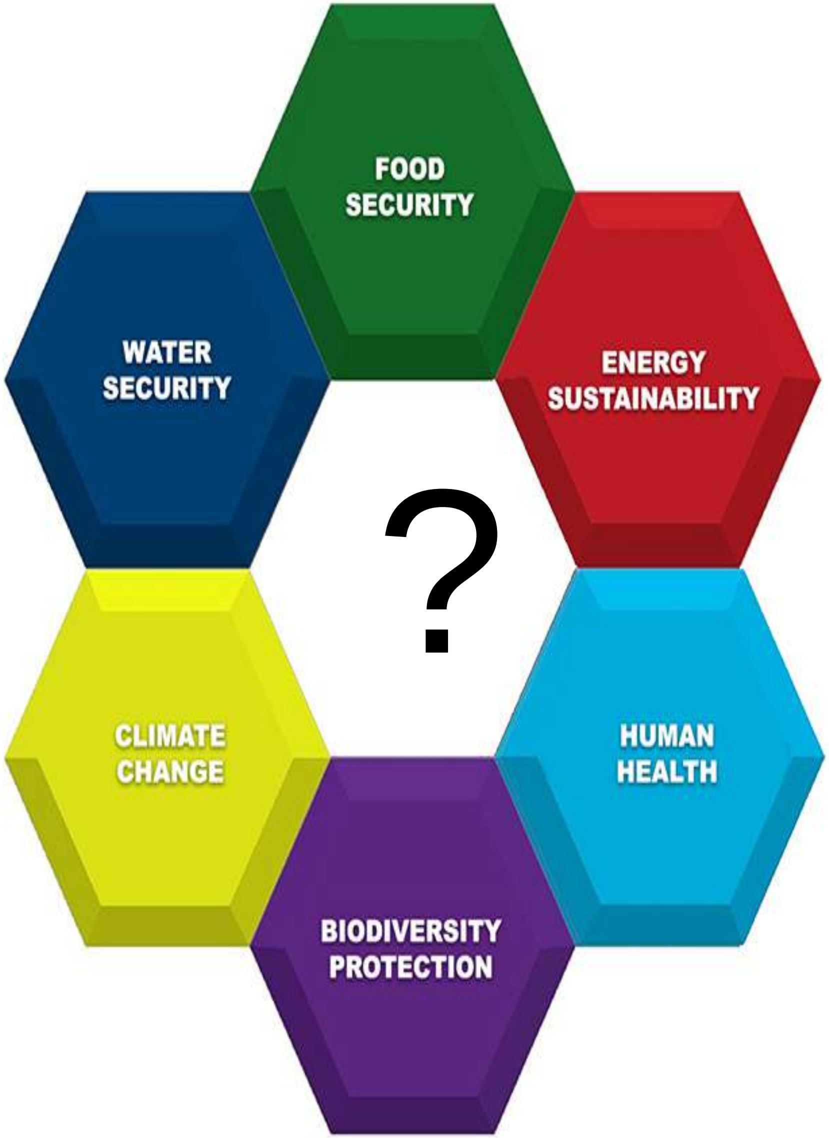
- Need a sustainable solution
- Soil can mitigate greenhouse gases
- Soil stores twice carbon (2700Pg) of atmosphere (780Pg) and biomass combined (575Pg) but has been dropping
- Soil is a buffer against extreme climate events

- Improve left expectancy and quality of life
- Nutrition - link to human nutrition largely trace elements
- Disease prevention - Soil recycling services

- Future options and resilience
- 25+% of biodiversity in soil
- Soil is the refugia …
- How much undiscovered biodiversity has been lost already?




All are interlinked




Something missing?


A nexus of seven global challenges

# Global Existential Challenges

The **Global** challenges

are also

The **Noble** challenges

# Why Soil Security?

1. Noble Global Existential Challenges

2. Concepts of valuing soil (by society)

# Concepts of Valuing Soil

- A concept that describes how humanity values and cares for soil

# Concepts of Soil…

Biophysical concept – soil horizon, profile, pedon, landscape etc.

Scientific concept – object of study, science of soil - soil science or science of soil materials

Societal concept – valuing and caring for soil for humanity

# There are several from the past….

- Soil conservation
- Land evaluation & capability
- Soil care

# …. and many from the present

- Soil function
- Soil quality
- Soil health
- Soil condition
- Soil change
- Soil resilience
- Soil ecosystem services

# …. and relatively some are fairly similar

Soil quality ≅ Soil health ≅ Soil condition

# …. A need to coalesce and generalise

- Clearly a plethora of concepts – but usually fairly narrow, sometimes vague, and generally biophysical

# …. Coalesce and generalise

- Concept should embrace the economic, social and policy settings, as well as the biophysical

# …. Coalesce and generalise

- We need a wider-ranging concept that addresses these manifold settings as well as recognising the place of earlier concepts


FOOD SECURITY
WATER SECURITY
ENERGY SUSTAINABILITY
SOIL SECURITY
CLIMATE CHANGE
HUMAN HEALTH
BIODIVERSITY PROTECTION

# SOIL SECURITY DIMENSIONS

Capability – biophysical (*soil function, capability*)

Condition – biophysical (*soil health, quality, condition, change*)

Capital – economic (*soil ecosystem services, natural capital*)

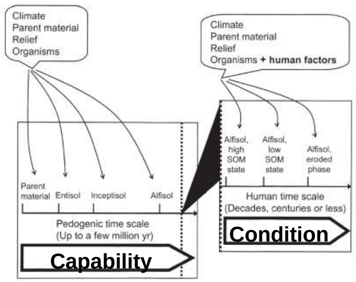
Connectivity – social (*soil care, awareness*)

Codification – policy, governance (*soil conservation*)

# Soil security

The five dimensions frame the soil functions, their value and utility.

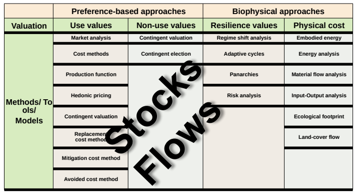
## Bio-physical




**Capability**

**Condition**

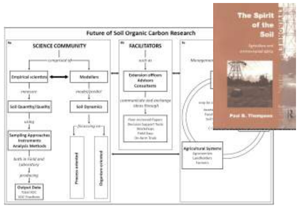
## Socio-Economic



| | Preference-based approaches | | Biophysical approaches | |
|---|---|---|---|---|
| Valuation | Use values | Non-use values | Resilience values | Physical cost |
| Methods/ Tools/ Models | Market analysis | Contingent valuation | Regime shift analysis | Embodied energy |
| | Cost methods | Contingent election | Adaptive cycles | Energy analysis |
| | Production function | | Panarchies | Material flow analysis |
| | Hedonic pricing | | Risk analysis | Input-Output analysis |
| | Contingent valuation | | | Ecological footprint |
| | Replacement cost method | | | Land-cover flow |
| | Mitigation cost method | | | |
| | Avoided cost method | | | |



**Capital**




**Connectivity**


**Codification**

McBratney A.B., Field D.J., Koch A., 2014. The dimensions of soil security. *Geoderma*, 213, 203-213

# Soil Functions

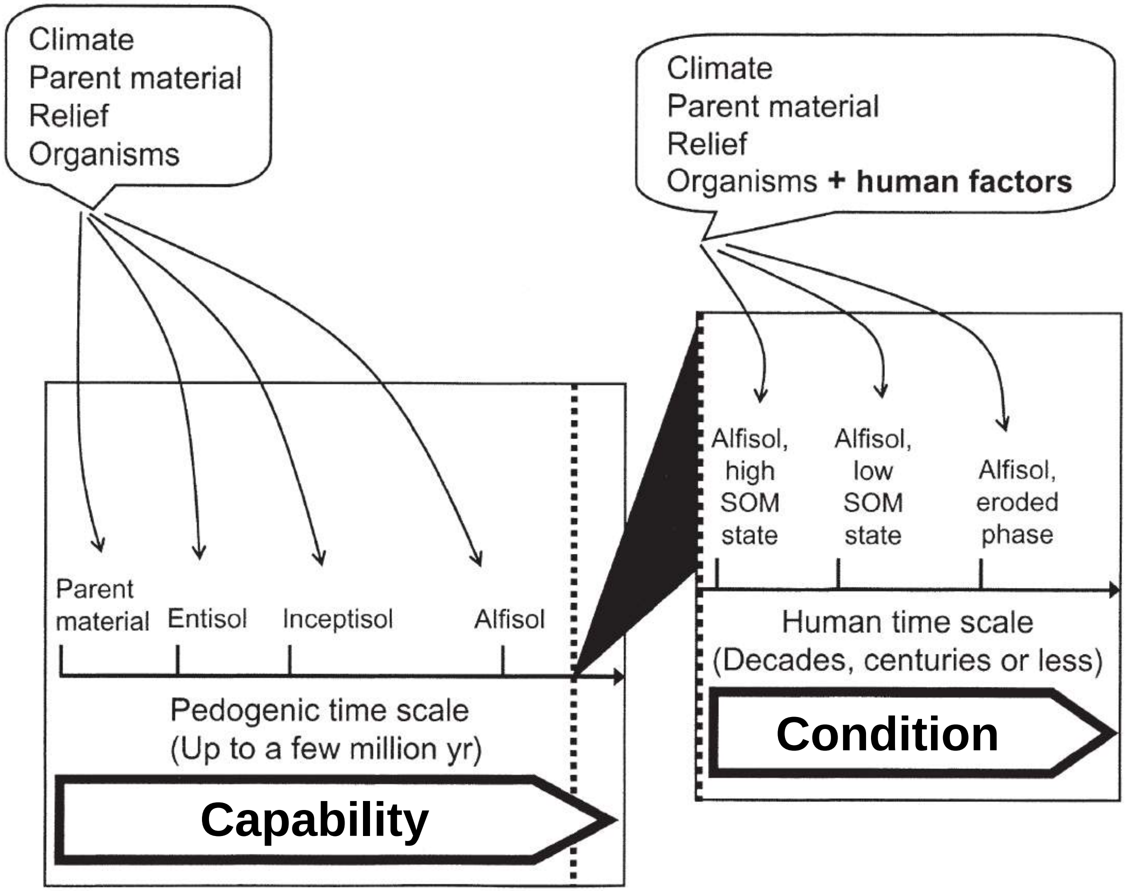
Seven soil functions

1. Biomass production
2. Storage, filtering, and transforming of nutrients substances and water
3. Biodiversity pool
4. Physical and cultural environment
5. Source of raw materials
6. Acting as a carbon pool
7. Archive of geological and cultural heritage

CEC, 2006, EU Commission Directive 34/2005/EC

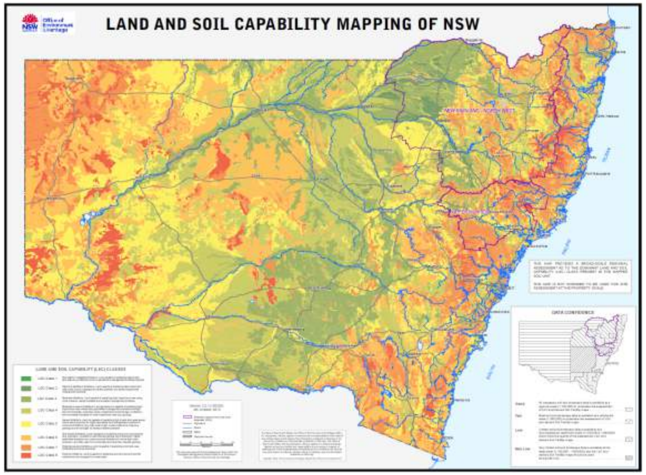
# Two of the dimensions of soil security

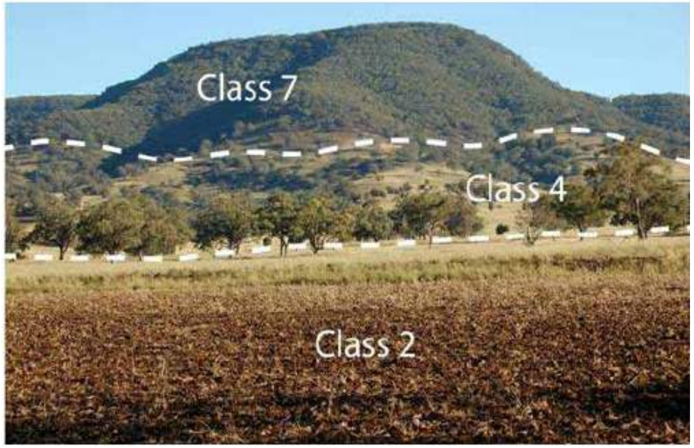
## Biophysical




Modified from Tugel *et al*.,2005. Soil change, soil survey and natural resource decision making. Soil Sci. Soc. Am. J. 69, 738-747.

# Capability




Soil depth
Rockiness
Soil Structure
Soil salinity
Soil acidity
Waterlogging (drainage)

## What can this soil do?

Characterised as being multi-functional

http://www.environment.nsw.gov.au/resources/soils/20120394lsc2s.pdf

# Biophysical dimensions

## Condition

Capability

*Inherent*

Soil Depth
Texture
Clay Type (*CEC*)
Stoniness

Condition

*Manageable*

Soil organic matter
Soil Nutrients
pH
Macropores
Bulk Density
Strength

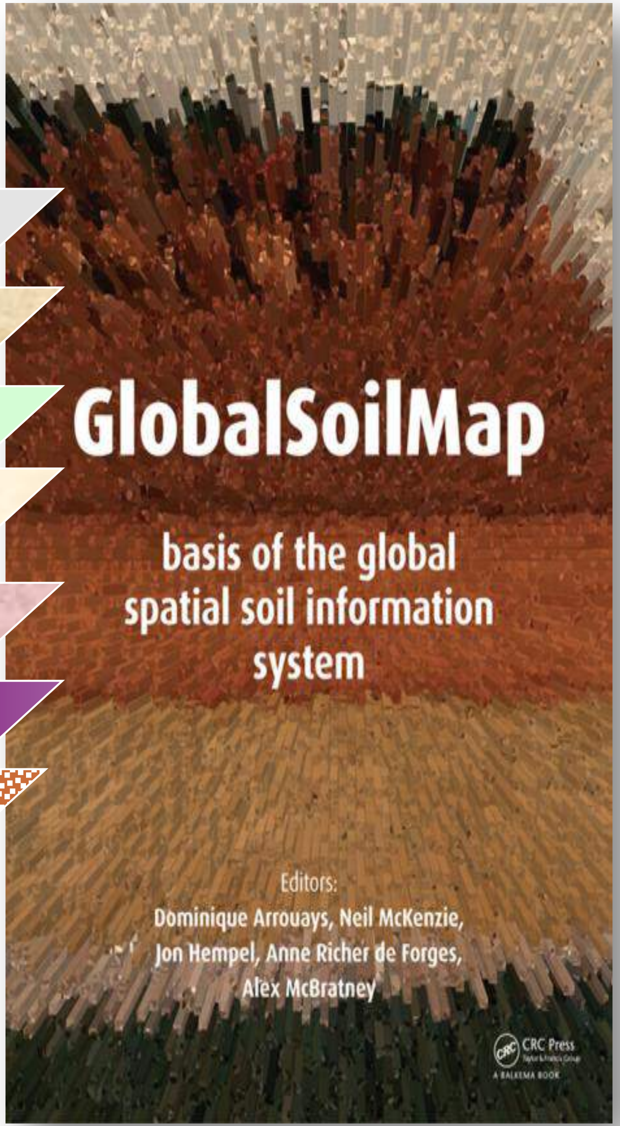
**Can the soil do this?**

Analogous with suitability

# GlobalSoilMap

Global consortium

- Detailed specifications
- 3 arc sec, ~90 m, ~100 yards, spatial resolution
- Quantitative soil properties to six fixed depth ranges to 2 m
- Uncertainty evaluated
- Bottom–up based on legacy data (~$40 billion prior investment)


Capable of quantifying aspects of capability

# Soil and Landscape Grid of Australia

- GlobalSoilMap product - properties (+ total N, total P) to Tier 1 GlobalSoilMap specifications - for Australia
- Brought most of Australia's disparate legacy soil data and maps together into a harmonised quantitative framework

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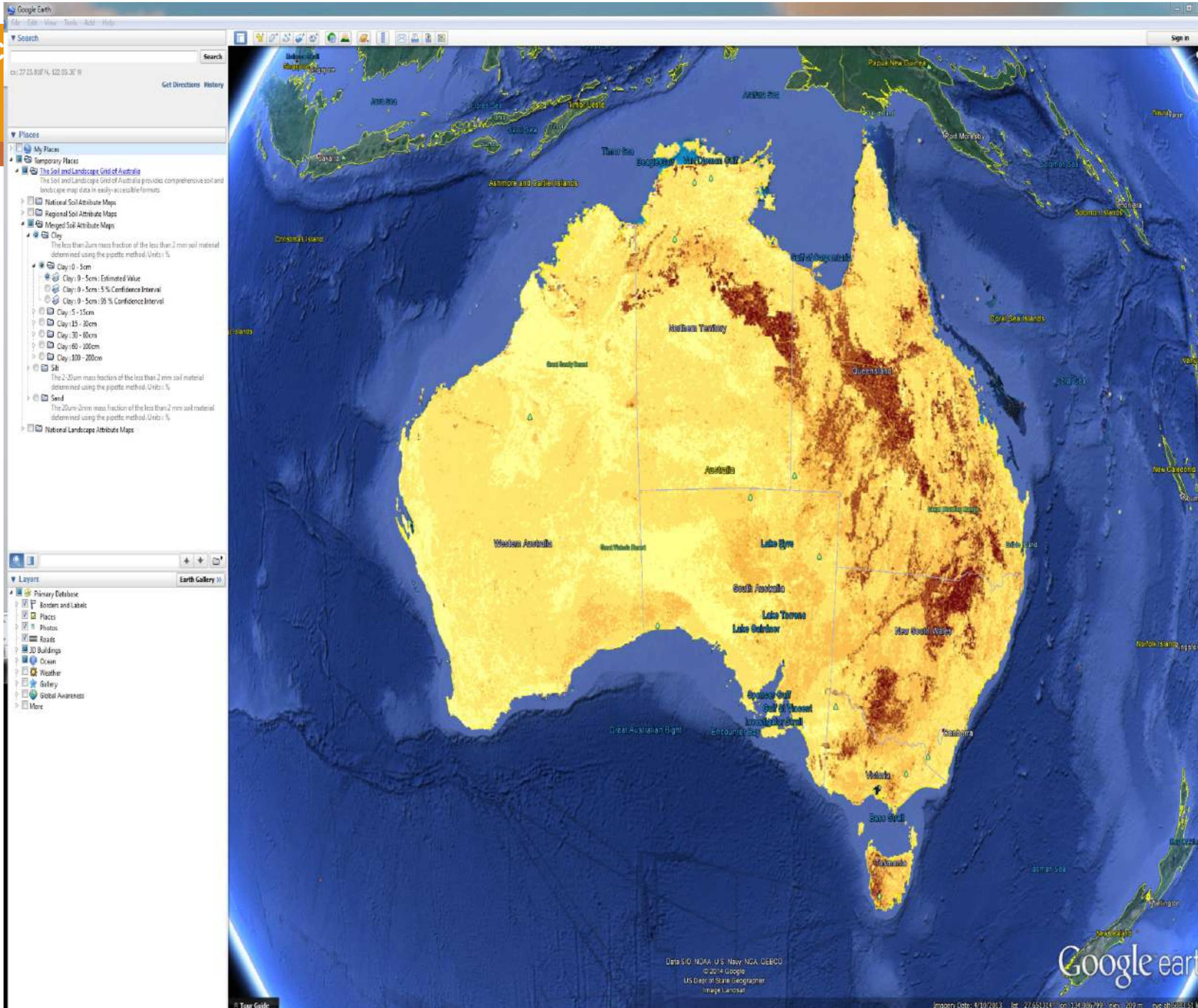

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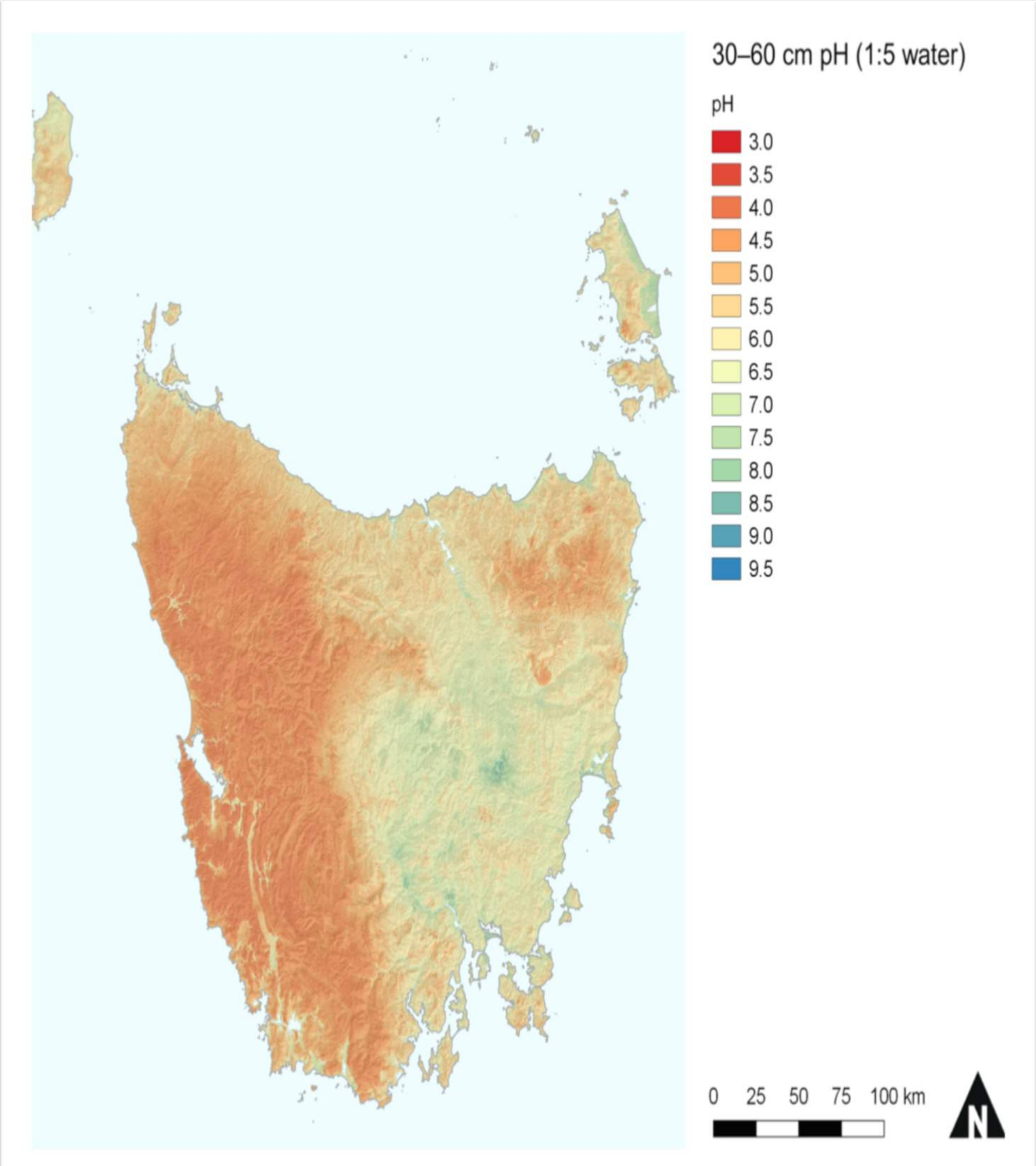

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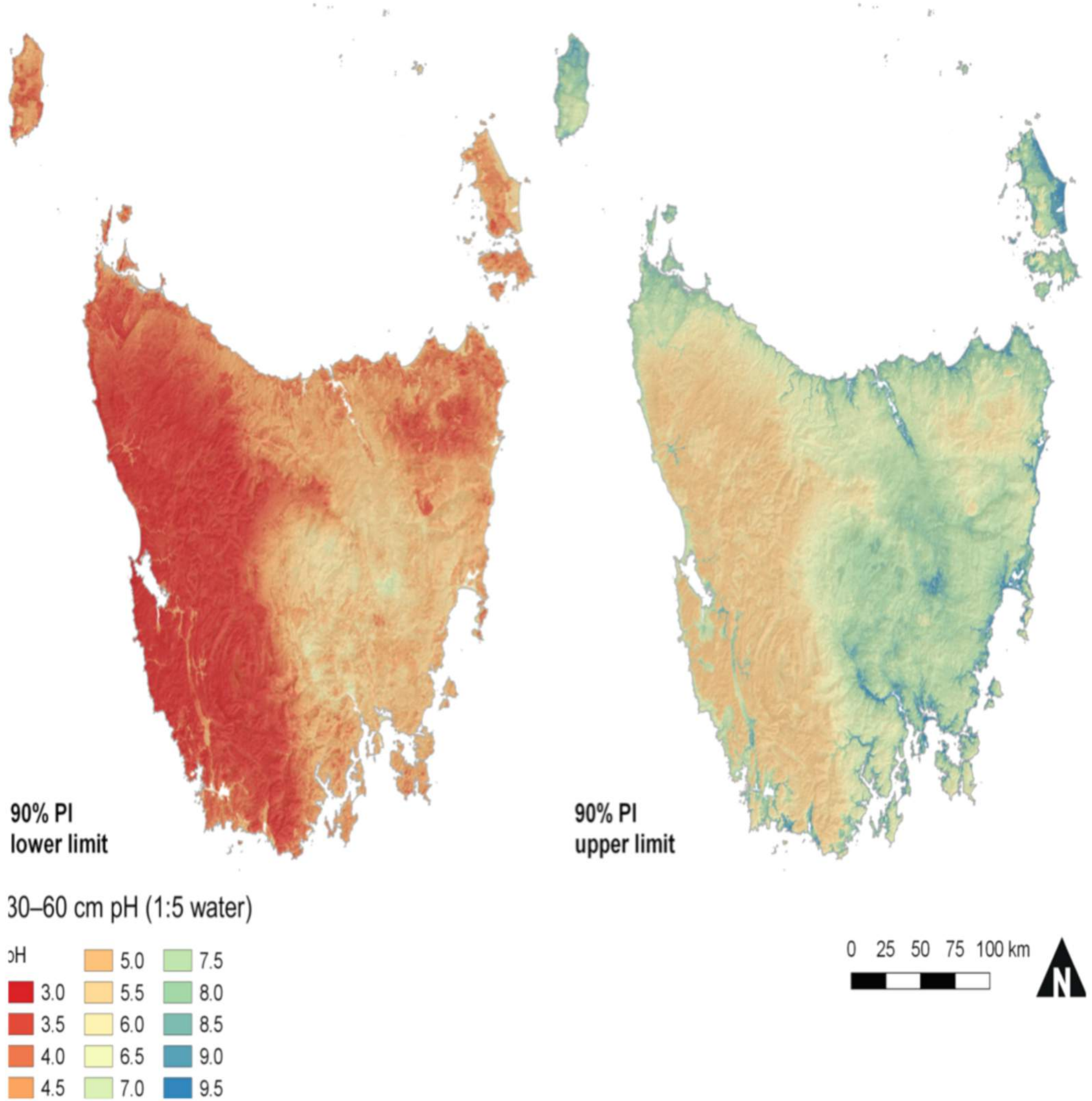

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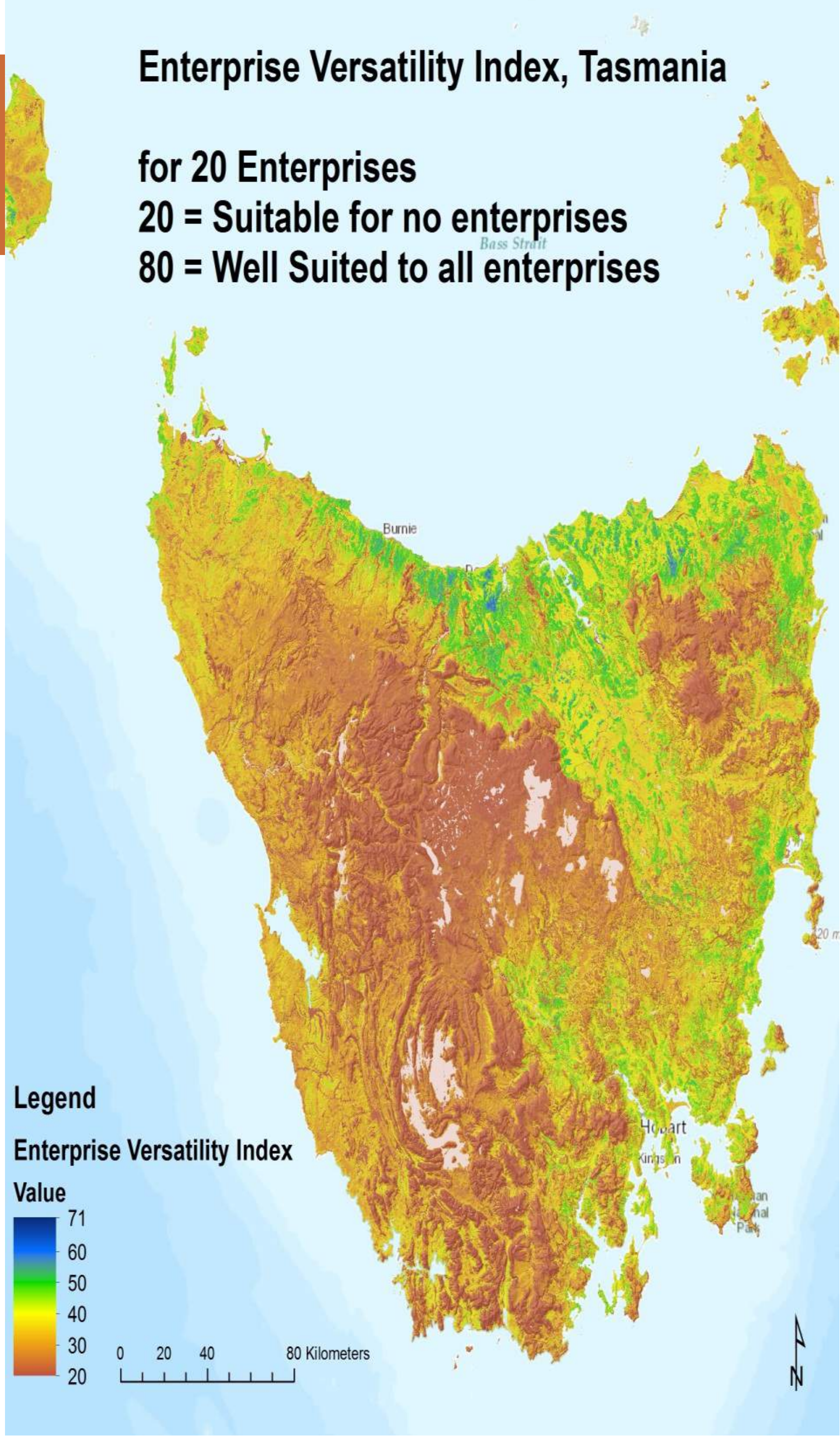
# Quantification

CAPABILITY relative to the function
BIOMASS PRODUCTION

for a range of 20 crops (enterprises)

Quantified by Versatility

Risk-based



# GlobalSoilMap

**The five C's of soil security prioritised by size on the impact GlobalSoilMap can make on their evaluation**

- **Capability**
- **Condition**
- **Capital**
- **Connectivity**
- **Codification**

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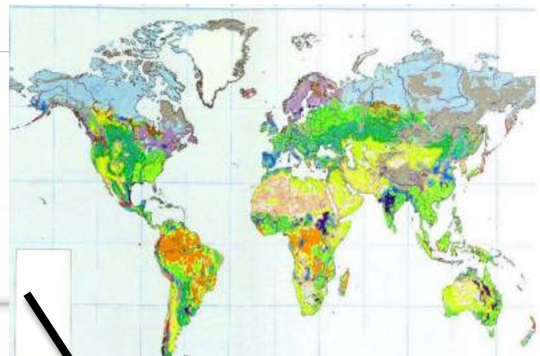
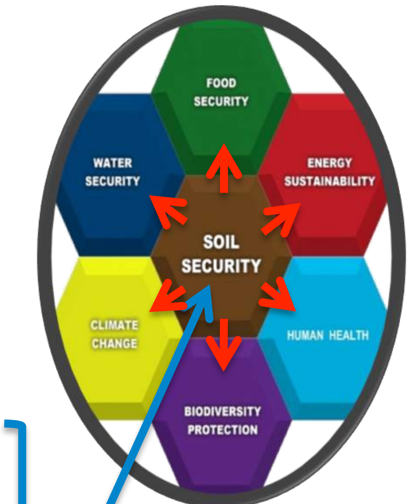
# GlobalSoilMap and Global Soil Security






**Capabi lity**
**Condition**
**Capital**
**Connectivity**
**Codification**

# The other three dimensions of soil security

Socio-economic dimensions

| | Preference-based approaches | | Biophysical approaches | |
|---|---|---|---|---|
| Valuation | Use values | Non-use values | Resilience values | Physical cost |
| Methods/ Tools/ Models | Market analysis | Contingent valuation | Regime shift analysis | Embodied energy |
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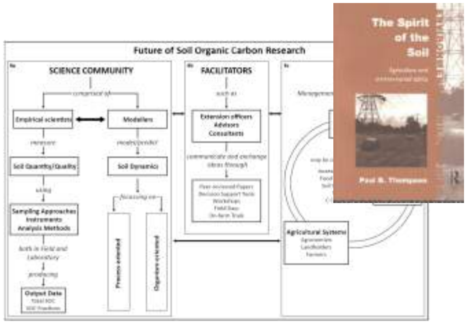
| | Avoided cost method | | | |

Stocks Flows

**Capital**

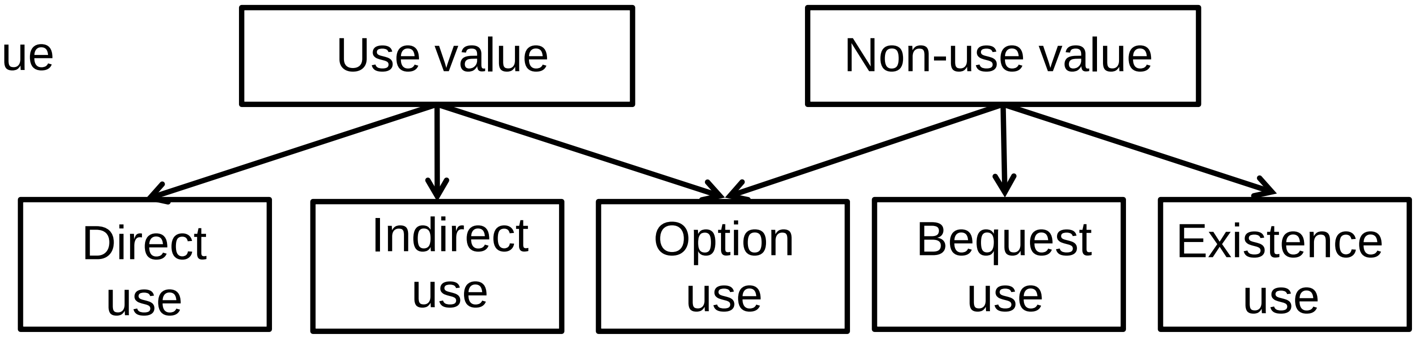



**Connectivity**


**Codification**

# Total Capital

Total value




- peat
- nutrients

- water purification
- flood mitigation

- organic matter

- avoid degradation
- biodiversity

- rare species

# Capital

## Stocks, processes, and benefits

**Stocks**

- Matter
  - Nutrients, minerals,
  - Soil water & air
- Energy
  - Soil temperature
  - Biomass
- Organisation
  - Soil structure
  - Biodiversity
  - Temporal continuity

**Processes**

Soil Formation

Nutrient Cycling

Biomass Production

*Soil Ecological Infrastructure*

| Services | Final Benefit | |
|---|---|---|
| Provisioning | Food | $ |
| Regulating | Flood mitigation | $ |
| Cultural | Recreation | $ |

Fischer, B. 2008. Ecosystem Services – Classification for valuation. *Biological Conservation* 141, 1167 – 1169 .

Robinson *et. al*., 2012. Natural Capital, Ecosystem Services, and Soil Change. Why soil must embrace the ecosystem approach. Vadose Zone J. 11, 5-10

# Capital

| Dimension | Soil Property | Selected Functions | | | |
|---|---|---|---|---|---|
| | | Biomass production | Storage, transforming | Biodiversity | Carbon storage |
| Capability | *Texture* | X | X | X | X |
| | *CEC* | X | X | | X |
| | *Stoniness* | X | X | | |
| Condition | *pH* | X | X | X | X |
| | *Nutrients* | X | X | X | X |
| | *Porosity* | X | X | X | |

Dominati E. *et al*. 2014. A soil change based methodology for quantification and valuation of ecosystem services… . *Ecological Economics* 100: 119-129.

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Costanza et al. 1997 Nature.  Cited by 13

articles

# The value of the world's ecosystem services and natural capital


obert Costanza*†, Ralph d'Arge‡, Rudolf de Groot§, Stephen Farber||, Monica Grasso†, Bruce Hannon¶, arin Limburg#*, Shahid Naeem**, Robert V. O'Neill††, Jose Paruelo‡‡, Robert G. Raskin§§, Paul Sutton|||| & Marjan van den Belt¶¶

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¶ Ecological Economics Research and Applications Inc., PO Box 1589, Solomons, Maryland 20688, USA



**he services of ecological systems and the natural capital stocks that produce them are critical to the functioning of the arth's life-support system. They contribute to human welfare, both directly and indirectly, and therefore represent art of the total economic value of the planet. We have estimated the current economic value of 17 ecosystem services or 16 biomes, based on published studies and a few original calculations. For the entire biosphere, the value (most of which is outside the market) is estimated to be in the range of US$16–54 trillion ($10^{12}$) per year, with an average of S$33 trillion per year. Because of the nature of the uncertainties, this must be considered a minimum estimate. Global ross national product total is around US$18 trillion per year.**


ecause ecosystem services are not fully 'captured' in commercial narkets or adequately quantified in terms comparable with economic services and manufactured capital, they are often given too ittle weight in policy decisions. This neglect may ultimately ompromise the sustainability of humans in the biosphere. The conomies of the Earth would grind to a halt without the services of cological life-support systems, so in one sense their total value to he economy is infinite. However, it can be instructive to estimate he 'incremental' or 'marginal' value of ecosystem services (the stimated rate of change of value compared with changes in cosystem services from their current levels). There have been nany studies in the past few decades aimed at estimating the alue of a wide variety of ecosystem services. We have gathered ogether this large (but scattered) amount of information and resent it here in a form useful for ecologists, economists, policy nakers and the general public. From this synthesis, we have stimated values for ecosystem services per unit area by biome, nd then multiplied by the total area of each biome and summed ver all services and biomes.

Although we acknowledge that there are many conceptual and mpirical problems inherent in producing such an estimate, we hink this exercise is essential in order to: (1) make the range of otential values of the services of ecosystems more apparent; (2) stablish at least a first approximation of the relative magnitude of lobal ecosystem services; (3) set up a framework for their further nalysis; (4) point out those areas most in need of additional esearch; and (5) stimulate additional research and debate. Most f the problems and uncertainties we encountered indicate that our estimate represents a minimum value, which would probably increase: (1) with additional effort in studying and valuing a broader range of ecosystem services; (2) with the incorporation of more realistic representations of ecosystem dynamics and interdependence; and (3) as ecosystem services become more stressed and 'scarce' in the future.

**Ecosystem functions and ecosystem services**

Ecosystem functions refer variously to the habitat, biological or system properties or processes of ecosystems. Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions. For simplicity, we will refer to ecosystem goods and services together as ecosystem services. A large number of functions and services can be identified[1–4]. Reference 5 provides a recent, detailed compendium on describing, measuring and valuing ecosystem services. For the purposes of this analysis we grouped ecosystem services into 17 major categories. These groups are listed in Table 1. We included only renewable ecosystem services, excluding non-renewable fuels and minerals and the atmosphere. Note that ecosystem services and functions do not necessarily show a one-to-one correspondence. In some cases a single ecosystem service is the product of two or more ecosystem functions whereas in other cases a single ecosystem function contributes to two or more ecosystem services. It is also important to emphasize the interdependent nature of many ecosystem functions. For example, some of the net primary production in an ecosystem ends up as food, the consumption of which generates respiratory products necessary for primary production. Even though these functions and services are interdependent, in many cases they can be added because they represent 'joint products' of the ecosystem, which support human


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# What is the Value of Soil Ecosystem Services?

| Ecosystem Service | Value $ [2015] $yr^{-1}$ | Proportion Contributed by Soil | 2015 billion$ |
|---|---|---|---|
| gas regulation | 2,119 | 0.1 | 212 |
| climate regulation | 1,081 | 0.1 | 108 |
| disturbance regulation | 2,811 | 0 | 0 |
| water regulation | 1,762 | 0.2 | 352 |
| water supply | 2,673 | 0.1 | 267 |
| erosion control | 910 | 0.5 | 455 |
| soil formation | 84 | 1 | 84 |
| nutrient cycling | 26,979 | 0.3 | 8,094 |
| waste treatment | 3,598 | 0.05 | 180 |
| pollination | 185 | 0 | 0 |
| biological control | 659 | 0 | 0 |
| habitat/refuge | 196 | 0.05 | 10 |
| food production | 2,190 | 0.5 | 1,095 |
| raw materials | 1,139 | 0.02 | 23 |
| genetic resources | 125 | 0.2 | 25 |
| recreation | 1,288 | 0 | 0 |
| cultural | 4,764 | 0.1 | 476 |

*Data source: Costanza et al. 1997 Nature. Table 2*

# What is the Annual Value of Soil Ecosystem Services?

**Total Annual Value for Soil Ecosystem Services = 11 trillion $**

**Comparisons:**
**US GDP = 17 trillion $**
**World GDP = 77 trillion $**

**Global Commodities**
**Wheat = 0.18 trillion $**
**Corn = 0.14 trillion $**
**Cotton = 0.08 trillion $**

# What is the Total Value of Soil Ecocystem Services?

**Assume 5% Return**

**Total ecososyem capital value of soil stock is 228 trillion $**

# What is the Value of Soil Ecosystem Services on an Areal Basis?

***Total***

| | |
|---|---|
| **per km$^2$** | **$253,000** |
| **per hectare** | **$2,530** |
| **per acre** | **$1,020** |

***Annual***

| | |
|---|---|
| **per km$^2$** | **$12,700** |
| **per hectare** | **$127** |
| **per acre** | **$51** |

# Connectivity

› ‘…*if there is no connection to the soil then the soil itself will more than likely be undervalued*….’

## Directly Connected

- Tenure – tenure/leasing, property use
- Knowledge & resources
- Proximity

## Indirectly Connected (*how much do I know or care?)*

- Societal connection – terroir
- Social capital – private sector strategies

# Codification

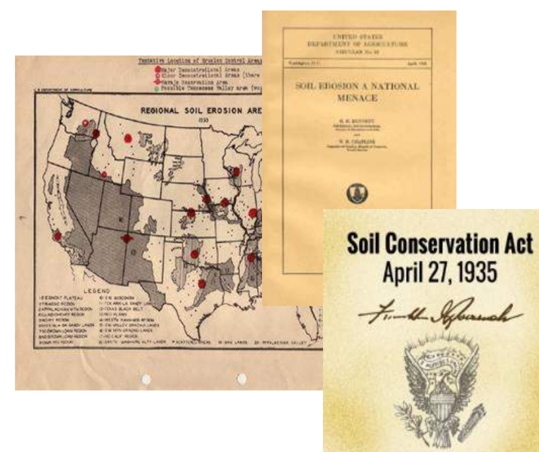
Policy, tools, initiatives


**International & Regional**

e.g. Global Soil Partnership (2011)

**National**

- Adopted a range of models (or approaches)
- Public
  - Carrots or Sticks
- Private Role
  - Lollipops or Trolls

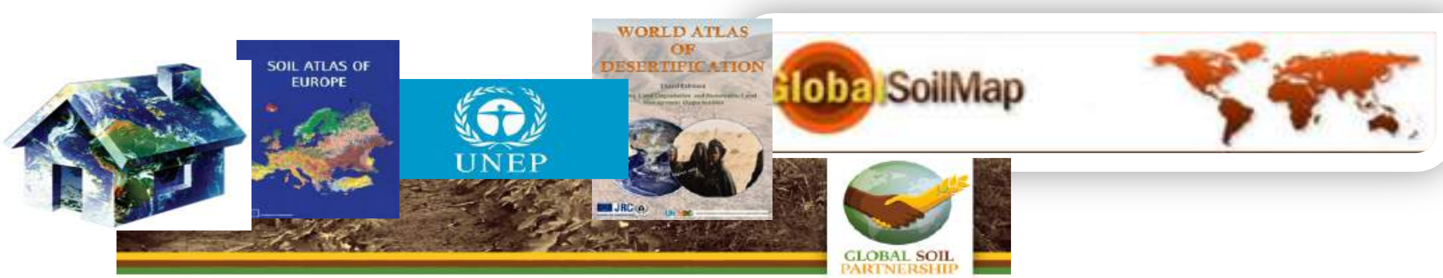
# Socio-economic

## Characteristics

- Provisioning, regulating, degradation services
- Clearly defined goals
- Interact/integrate with other policies, i.e. social, economic, etc
- Sufficient models (ISTA) and assessment procedures with clearly defined indicators (soil properties & processes), thresholds, etc
- Range of policy instruments that affect compliance – e.g. voluntary (incentives), or obligatory.

**Are the soil functions explicitly recognised?**

**Millennium Ecosystem Assessment**




Steiner F. *et al.* 1987. Soil conservation policy in the United States. *Environmental Management*, 11, 209 - 223

# Threats to the soil's security

| Dimension | Threats to soil security |
|---|---|
| Capability | Erosion, landslides, sealing by infrastructure, source of raw materials |
| Condition | Contamination, loss of organic matter, compaction and other physical land degradation, salinization, acidification |
| Capital | Inadequate assessment of the soil asset, *soil stock*, and *processes* that; *support, regulate, degrade*, and *cultural* |
| Connectivity | Inadequate knowledge of land managers, lack of recognition of soil services and soil goods by society |
| Codification | Incomplete policy framework, inadequate or poorly designed legislation, lack of certifications |

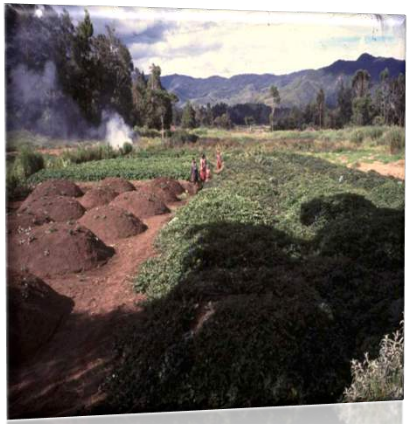
# a potential GLOBAL SOIL SECURITY GOAL

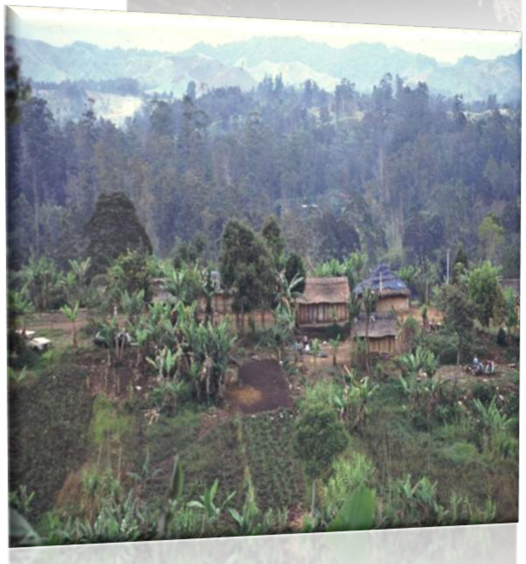
Increase carbon concentration of agricultural topsoils by 20% by 2030

# SOIL SECURITY - DIMENSIONS

1. **Capability** – biophysical (strategic)
2. **Condition** – biophysical (tactical)
3. **Capital** – economic, natural capital
4. **Connectivity** – social, educational
5. **Codification** – policy, governance

# Andisols, Shifting cultivation, Papua New Guinea





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# Rhodo[xer/ust]alfs, dryland wheat production, NSW, Australia

# CONCLUSIONS

Soil Security is a timely (and strategic) concept

→

It arises from both top-down (global challenge) and bottom-up (societal value) considerations

→

It is homologous in conception to/ with food and water security

→

Major challenge is to measure and manage its dimensions – '*if you treasure it, measure it*'

# Bibliography

McBratney, Field & Koch (2014)
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*2nd Symposium on Soil Security*
*Institut Curie, Paris, December 5-6, 2016*

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# Grazie per l'ascolto