From What to How?

Ecosystem services valuation methods: appropriate scale and scope in agriculture

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Price of Food

Environmental benefits (+ve)

$

Environmental costs (-ve)

Transformation of agriculture and food systems based on ecosystem services (ES) valuation

Agriculture poses risks to Ecosystems

Drivers of Ecosystem Change

1.89

1.66

236

1.5

Cropland billion hectares

135

EQUATOR

0.74

10.1

EQUATOR

0.5

87

Fertilisers million tonnes

6.55

Pesticides consumption million tonnes

3.75

20

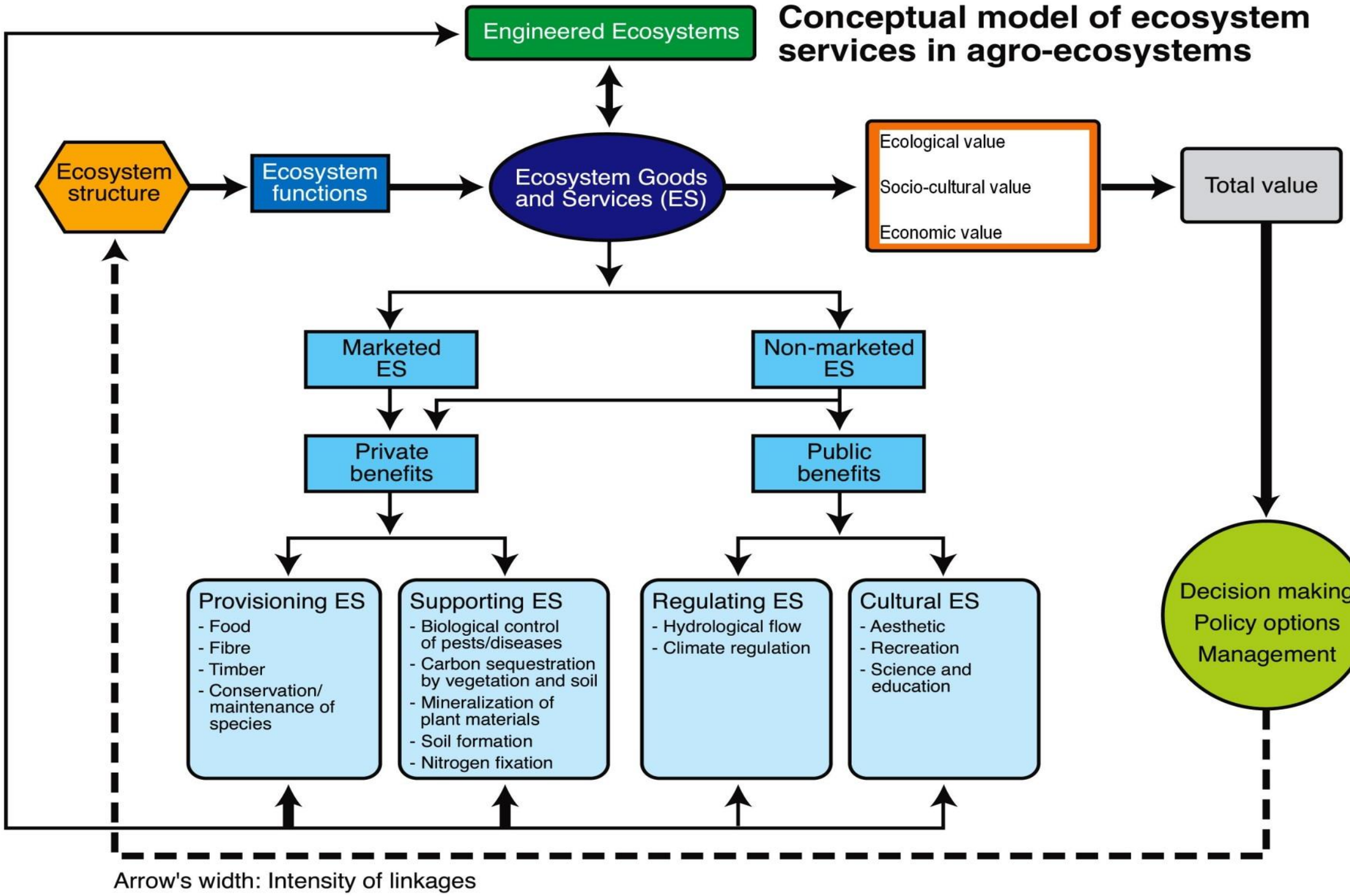
3

1900 1950 2000 2020 2050

Cultivated Systems:
Areas in which at least 30% of the landscape is cultivated

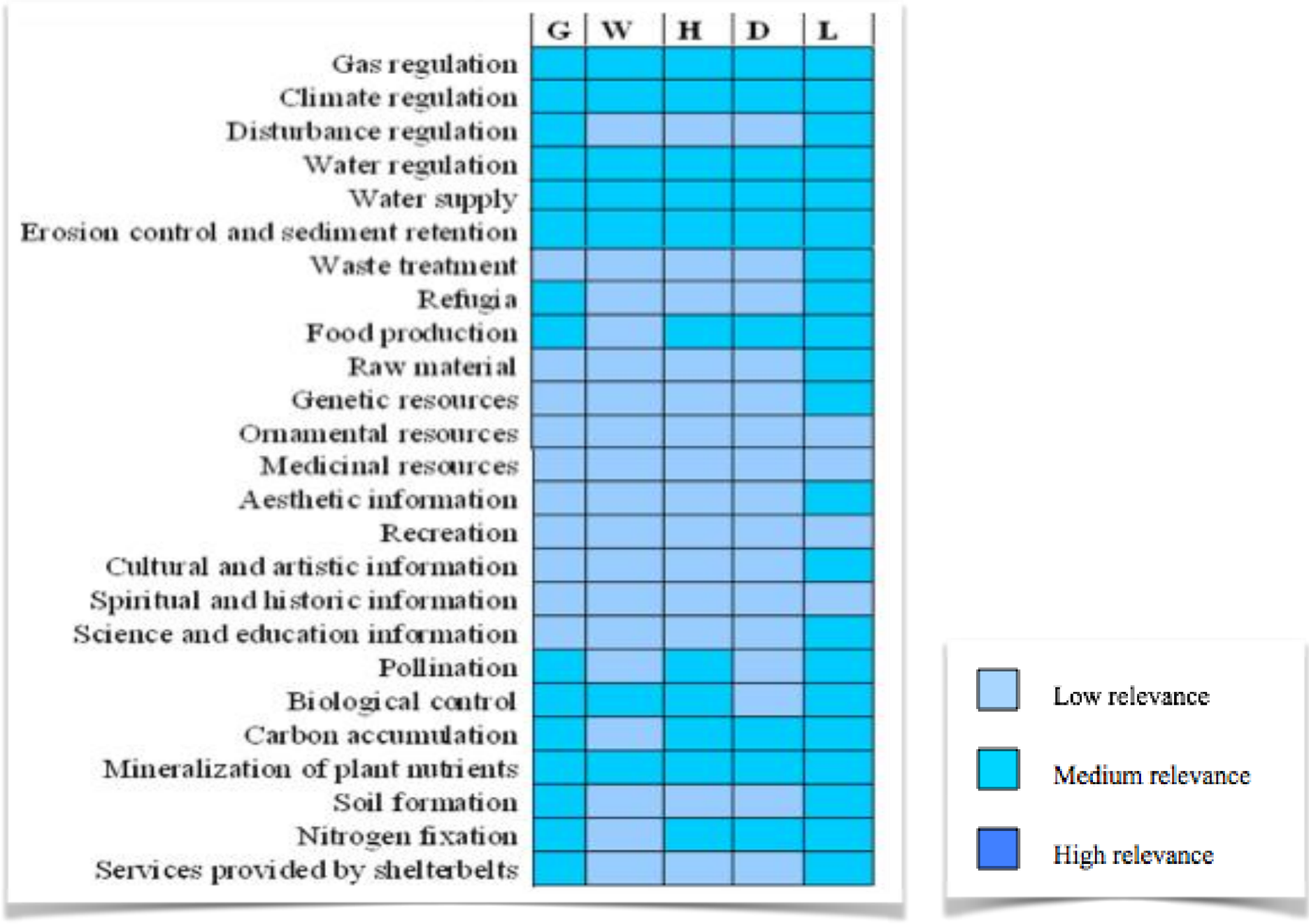
Source: Millennium Ecosystem Assessment

Ecosystem Services in Agriculture



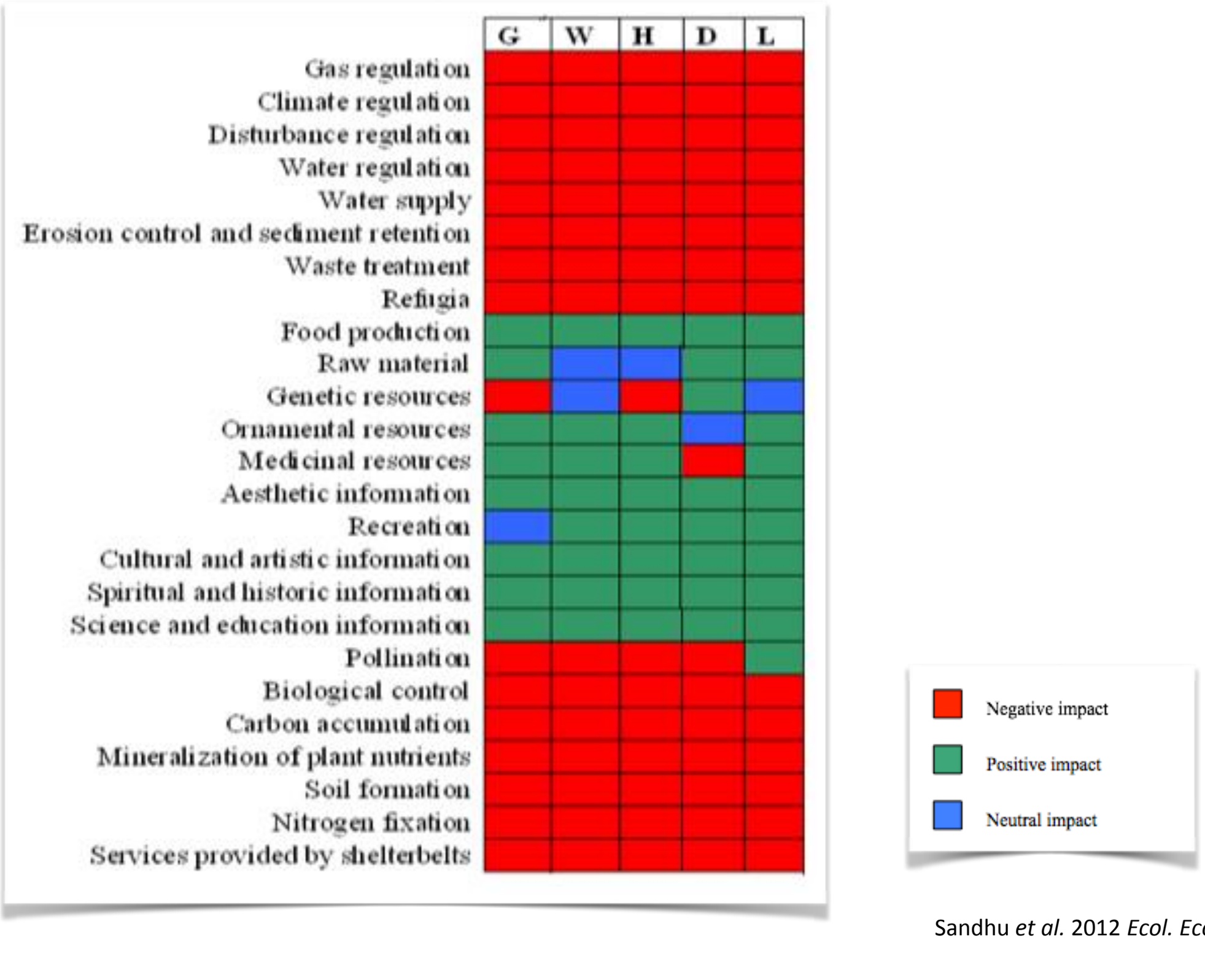
Sandhu *et al*. 2010 *Env Sc Policy*, Sandhu *et al.* 2012 *Ecol. Econ*., Sandhu *et al.* 2013

Relevance of ES to agriculture



Sandhu *et al.* 2012 *Ecol. Econ*.

Impacts of agriculture on ES



Sandhu *et al.* 2012 *Ecol. Econ*.

How to measure ES in Agriculture?

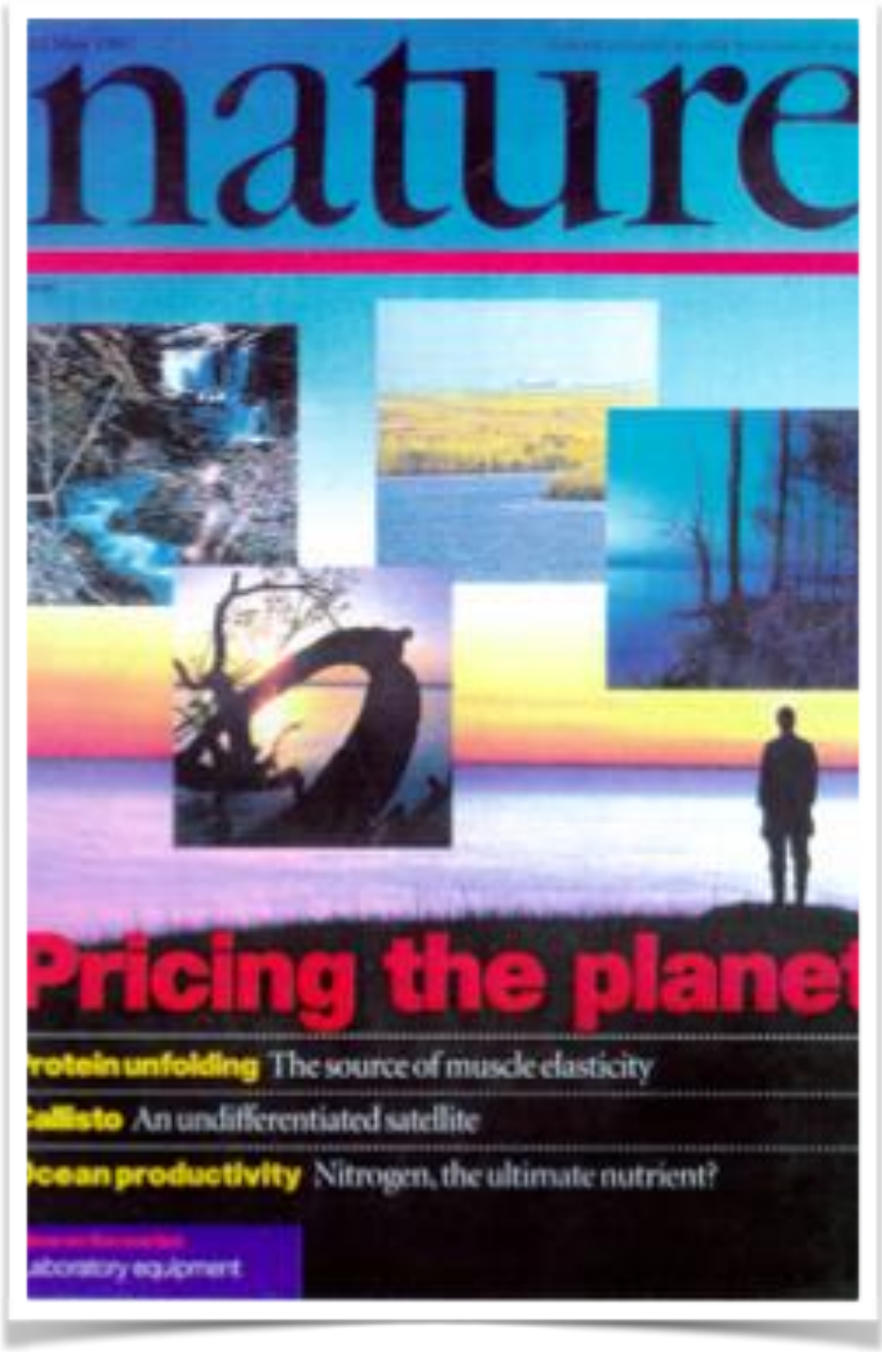
ES Valuation
Top down value transfer approach

$ value of ecosystem services
for the world:

US $ 33,000,000,000,000 p.a.

Gross global GDP:
US $ 18,000,000,000,000 p.a.
(Nature 1997)

Current ES value $125 trillion/year
ES losses $4 - 20 trillion/year
(GEC 2014)



Bottom-up valuation approach

ECOLOGICAL ECONOMICS 64 (2008) 835–848

available at www.sciencedirect.com

www.elsevier.com/locate/ecolecon

ANALYSIS

The future of farming: The value of ecosystem services in conventional and organic arable land. An experimental approach

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Bottom-up approach

- Bio-physical measurements based on experimental work
- 12 ES
- Economic value

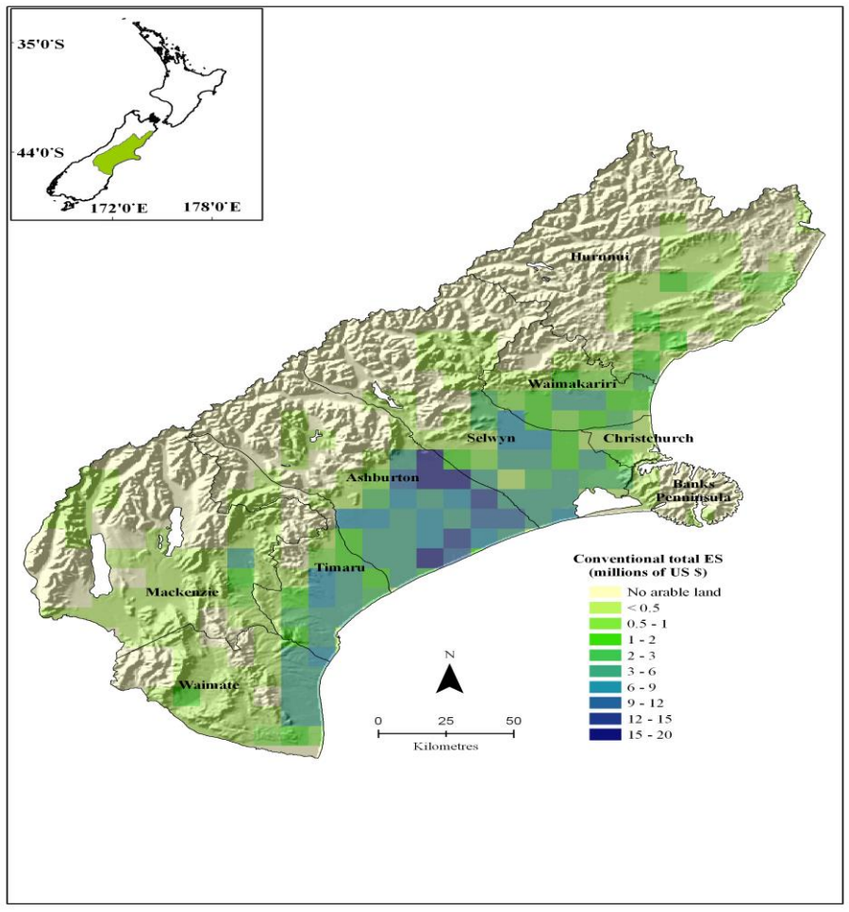
Table 1 – Summary of mean and range of economic value of ecosystem services in organic and conventional fields

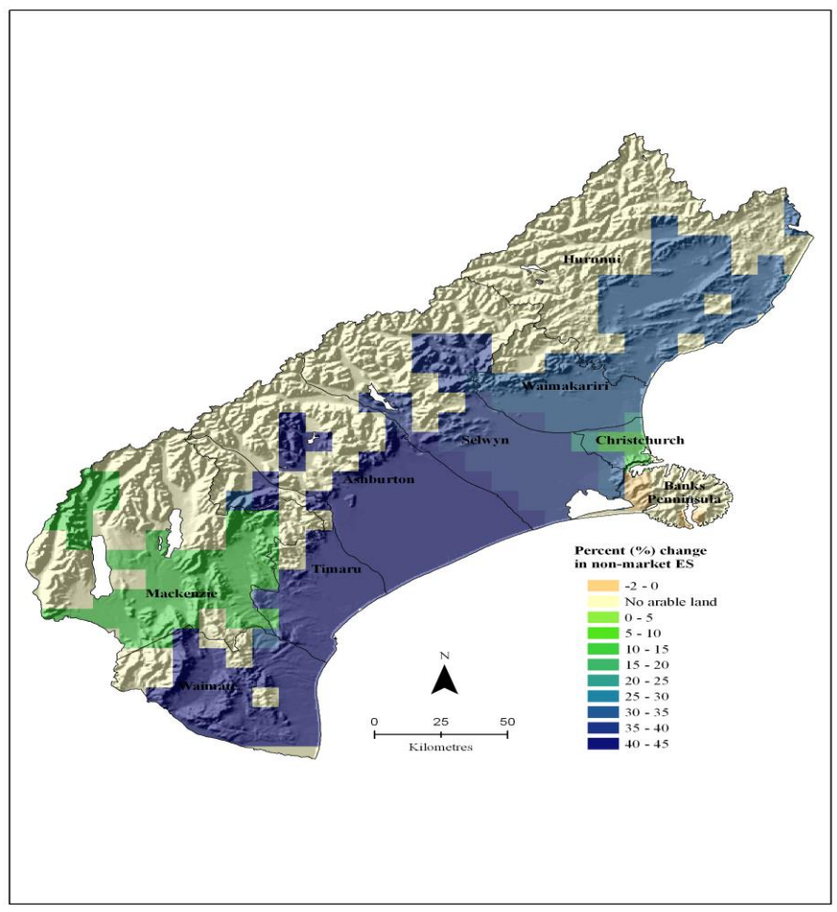
	Ecosystem services	Economic value (range) in US $ ha^{-1}yr^{-1}	
		Organic fields	Conventional fields
1	Biological control of pests	50 (0–100)	0 (0–0)
2	Mineralisation of plant nutrients	260 (26–425)	142 (30–349)
3	Soil formation	6 (0.7–11)	5 (2–9)
4	Food	3990 (1150–18900)	3220 (840–14000)
5	Raw materials	22 (0–224)	38 (0–298)
6	Carbon accumulation	22 (0–210)	20 (0–210)
7	Nitrogen fixation	40 (0–92)	43 (0–92)
8	Soil fertility	68 (53–82)	66 (54–73)
9	Hydrological flow	107 (−111–190)	54 (−118–194)
10	Aesthetic	21 (21–21)	21 (21–21)
11	Pollination	62 (0–438)	64 (0–455)
12	Shelterbelts	880 (0–472)	200 (0–617)
	Total economic value of ES	4600 (1607–19,412)	3680 (1263–14,570)
	Non-market value of ES	1480 (452–5237)	670 (48–1235)

Sandhu et al. 2008 *Ecological Economics*

Field level

Spatial application to regional scale for policy





Increased percentage in non-market ES when half of the conventional area is converted to organic farming

Sandhu *et al.* 2008 *Ecol. Econ*.

Field level > Regional level

Combined food, fodder and energy system
Copenhagen University, Denmark

- Biomass hedges and crops
- Crop rotation
- Organic management
- Energy neutral

Table 3. The monetary value and field assessment of ES in pastures, cereals, biomass belts, and the CFE system.

	ES value USD ha^{-1} y^{-1}*			
ES	**Pasture**	**Cereals**	**Biomass**	**CFE**
Biological control of pests	13	0	12	7
N regulation: fixation and mineralization	434	217	15	294
Soil formation	11	17	—	13
Food and fodder production	216	515	0	329
Raw material (biomass) production	0	0	600	60
Carbon accumulation	37	25	60	34
Hydrological flow	76	86	42	77
Aesthetics	262	138	332	213
Pollination	85	0	85	47
Total economic value of ES	1134	998	1146	1074
Nonmarket ES value (NMV)	918	483	546	685
NMV/ES value	0.81	0.48	0.48	0.64

Field assessment of each ES in pasture, cereals, and biomass belts

Field process and/or state		**Pasture**	**Cereals**	**Biomass**
Predation rate of aphids (% removal 24 hr^{-1})	ES1	20	53	0
Predation rate of eggs (% removal 24 hr^{-1})	ES1	45	38	0
N regulation: mineralization of plant nutrients (%)	ES2	14.5	16.7	17.1
Earthworm density (number m^{-2})	ES3	104	160	0
Food/fodder (t dry matter ha^{-1})	ES4	6.1	4.1	0
Yield of wood (t dry matter ha^{-1})	ES5	0	0	10
Carbon residue (t ha^{-1})	ES6	3.7	2.5	6
Water recharged into ground (mm ha^{-1})	ES7	382	432	212
Aesthetic (USD ha^{-1})	ES8	262	138	332
Pollination (hives)	ES9	0.5	0	0.5

* The ES value of the CFE system was calculated based on the ratio of 45 : 45 : 10 as between pasture, cereals, and biomass belts.

Porter, Sandhu, Wratten, Costanza, Sigsgaard 2009 *Ambio*

Field level → Regional level → Continental level

Bold ideas and unjustified assumptions are the only way to advance science

Karl Popper

Extrapolation to global scale for policy

- Biophysical measurements at field scale
- Economic value at field $/ha including input/output data
- Data from 110 countries, temperate regions, 4 crops, inputs (fertilisers and pesticides) and outputs data.
- Calibrate localised input/output data, apply range of values of ES (from previous studies) to these sites
- Estimate ES values at each site
- Provide global estimates of ES values

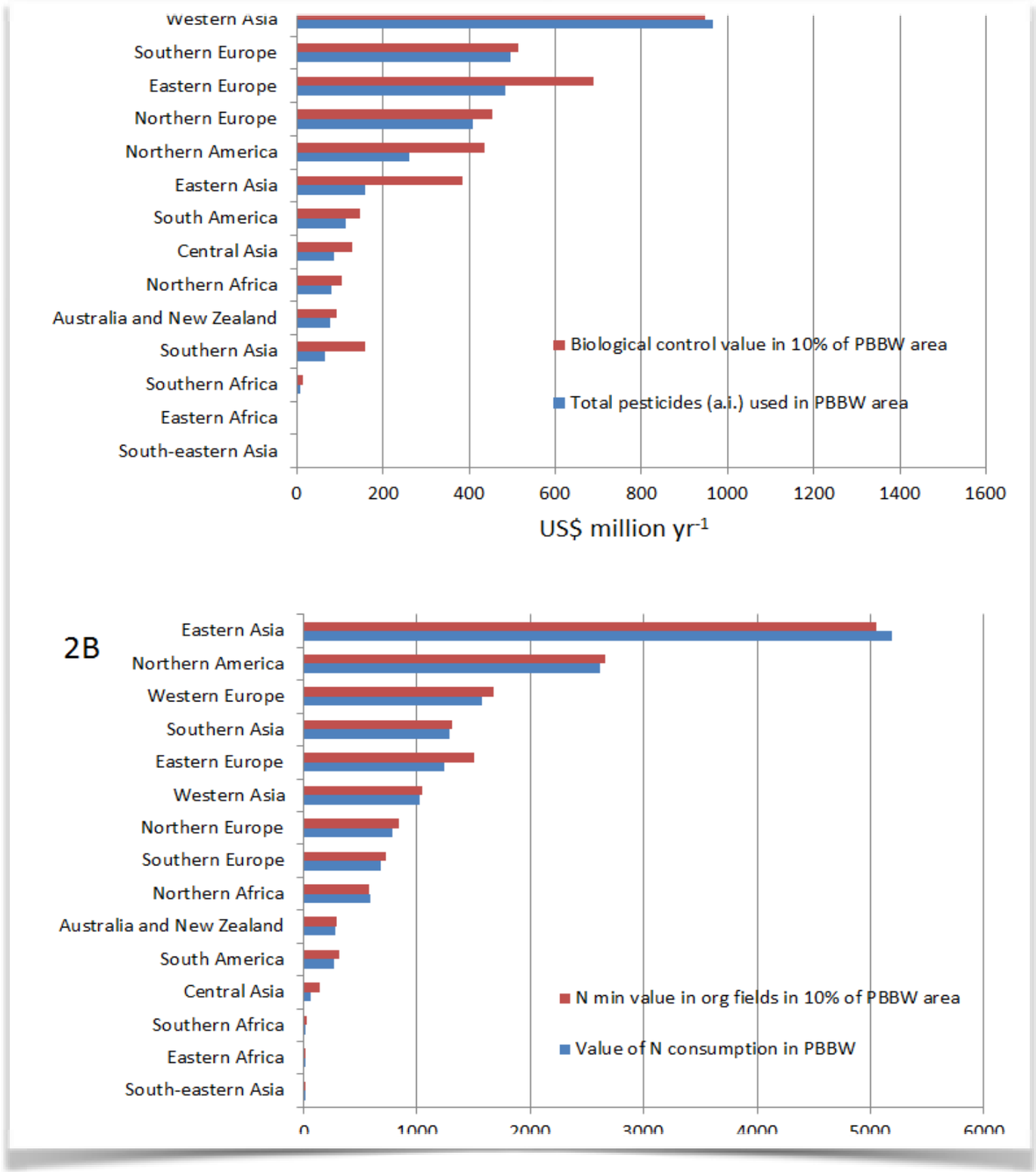
Sandhu, Wratten, Costanza, Pretty, Reganold, Porter 2015 *PEER J*

Total value of inputs in 15 global regions

	Regions	Total value of pesticides and fertilisers in PBBW area (US$ million yr^{-1})	Total value based on two ES in PBBW area (US$ million yr^{-1})	Total value based on two ES in 10% of PBBW area (US$ million yr^{-1})
1	Eastern Africa	0.3	0.8	0.3
2	Northern Africa	665.9	836.1	682.9
3	Southern Africa	28.9	115.7	37.6
4	South America	381.5	1165.7	459.9
5	Northern America	2872.4	5139.6	3099.1
6	Central Asia	154.1	1323.8	271.0
7	Eastern Asia	5347.6	6225.8	5435.4
8	Southern Asia	1347.2	2615.0	1474.0
9	South-eastern Asia	0.02	3.1	0.3
10	Western Asia	1994.6	2026.5	1997.9
11	Eastern Europe	1720.8	6487.5	2197.5
12	Northern Europe	1192.5	2191.4	1292.4
13	Southern Europe	1180.4	1731.2	1235.4
14	Western Europe	2871.8	4286.4	3013.2
15	Australia and New Zealand	360.5	531.8	377.7
	Total	20119.1	34680.9	21575.3

Field level → Regional level → Continental level → Global level

ES values for policy scenarios



Sandhu *et al.* 2015 *PEER J*

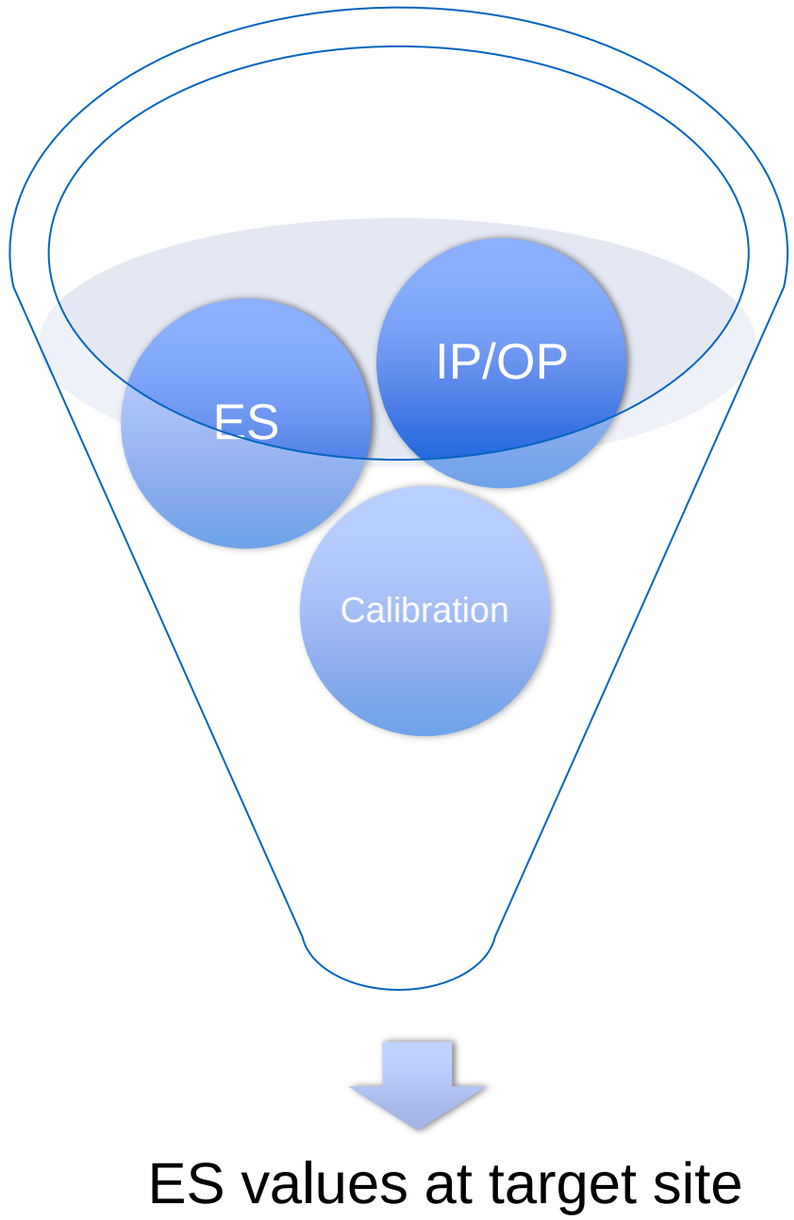
Application to TEEB AF

Step-by-step process for estimating ES values from agriculture: bottom-up approach approach

A. ES value database from field studies

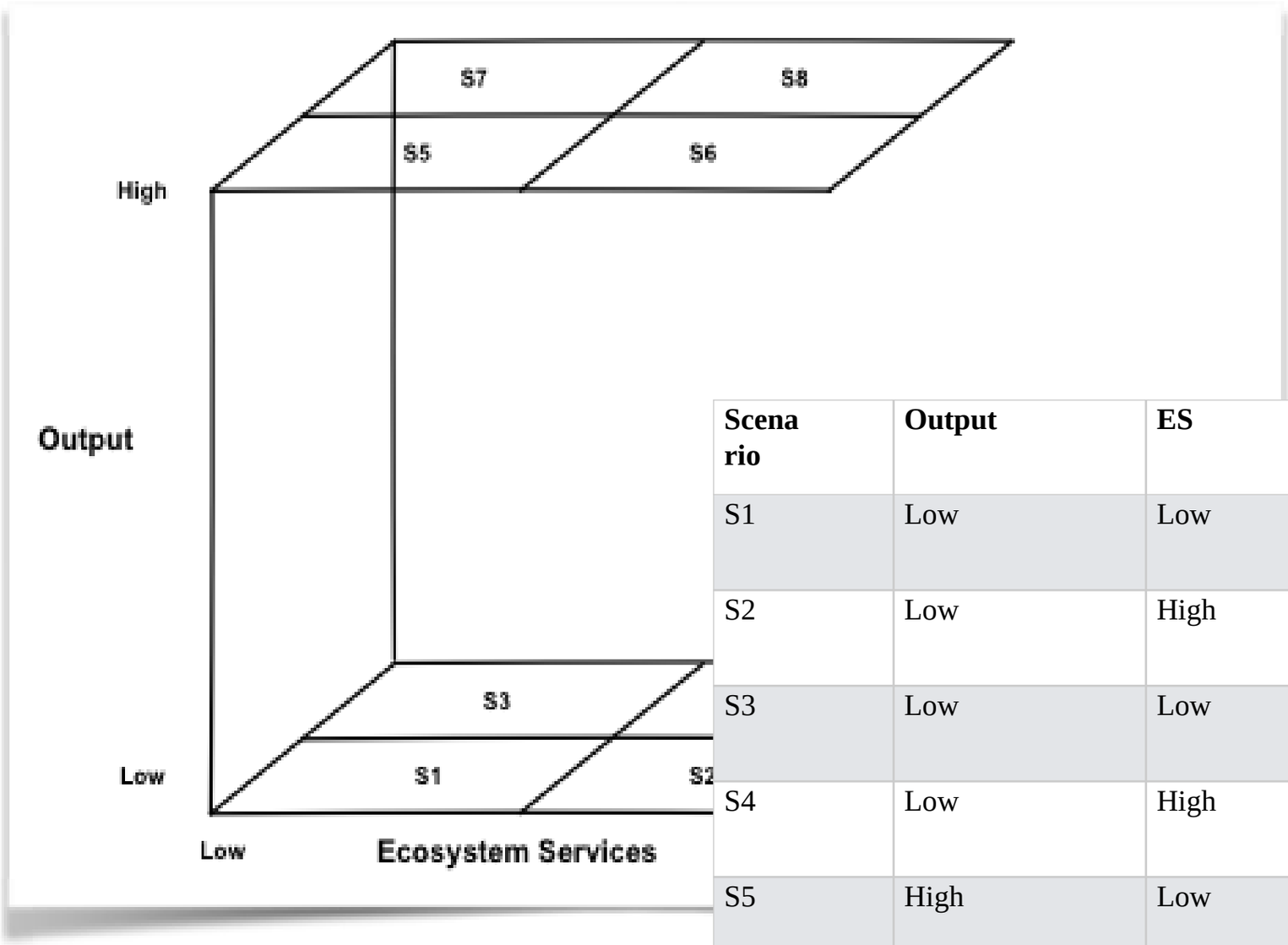
B. Application to different sites

C. Stocks and flows



Procedure developed and tested

Explore ES production and management cost for rolling out policy



Scenario	Output	ES	Cost	Agro-ecosystems
S1	Low	Low	Low	Poor systems
S2	Low	High	Low	Ideal for environmental outcomes
S3	Low	Low	High	Degraded systems
S4	Low	High	High	Multifunctional systems
S5	High	Low	Low	Current monocultures
S6	High	High	Low	Optimal systems
S7	High	Low	High	Changing ecosystems
S8	High	High	High	Unsustainable

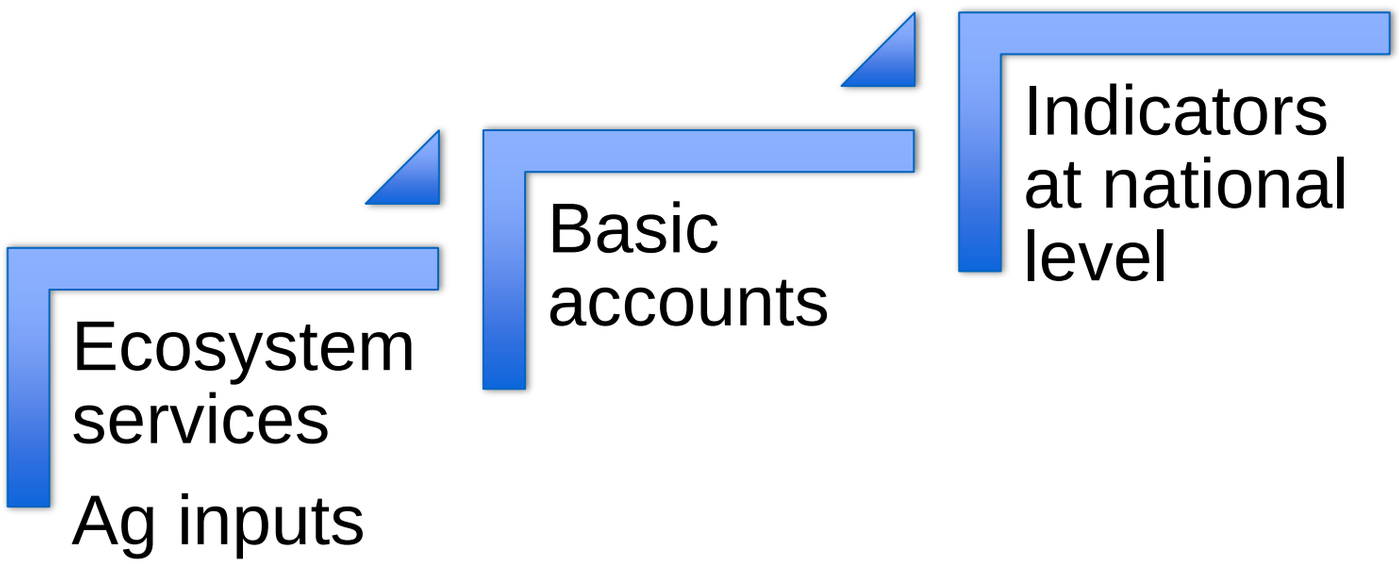
Sandhu *et al.* 20153 ES Book

Points to consider for SEEA AG

- SEEA Ag relevance for national accounting: Consistency in methods to measure and monitor ES to be used for inclusion in GDP in longterm.

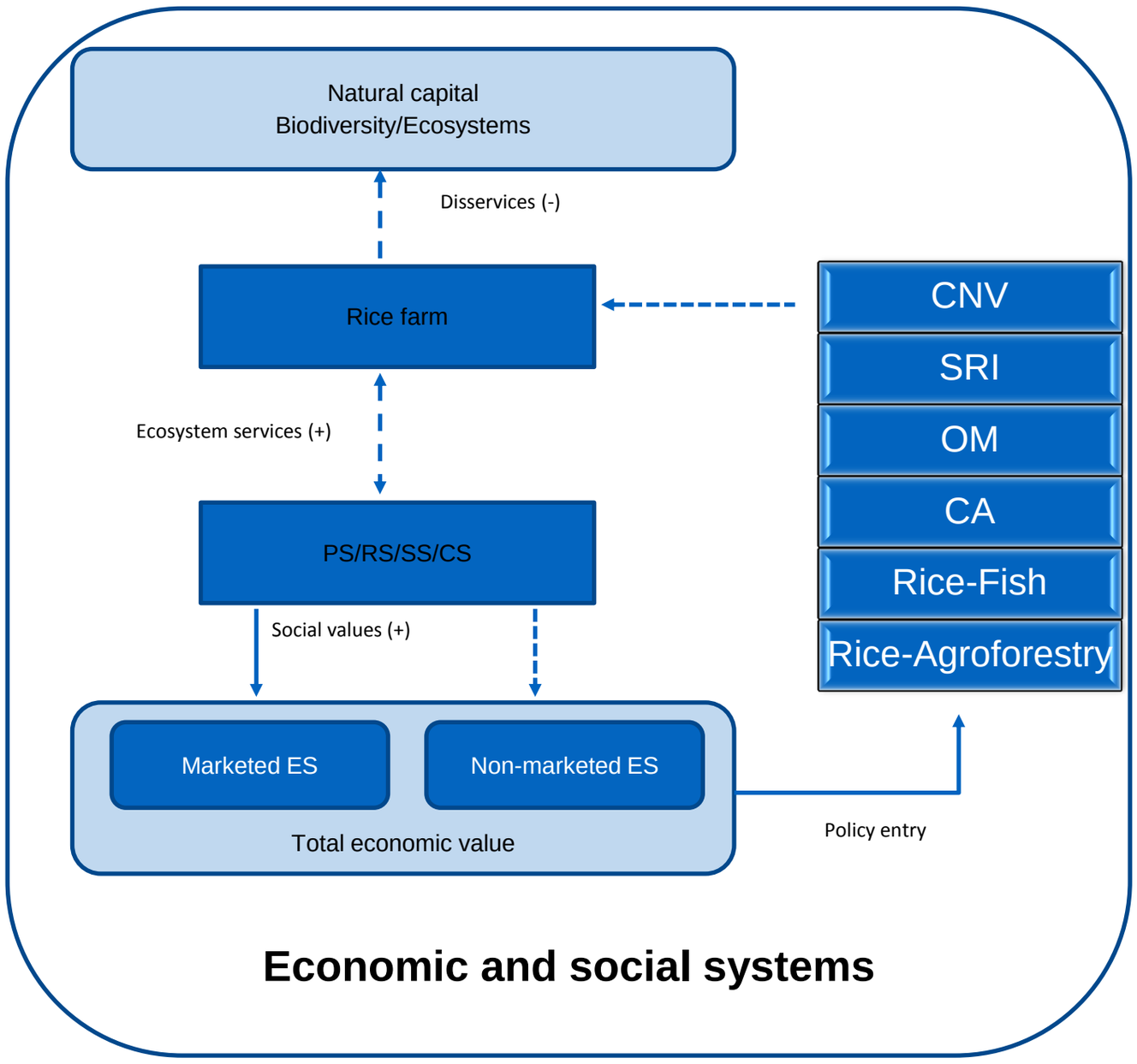
- SEEA Ag only accounts for Ag production, water resources, GHG emissions, land use change

- Bottom up approach accounts for all ES and not just costing for environment pollution



Scale and scope in TEEB A&F

Rice Agro-ecosystems



Broken arrow: Invisible value or cost
Solid arrow: Visible value

Different Management Practices in Rice - Philippines

1. Conventional (Recommended) Management Practices (CMP/RMP)
2. System of Rice Intensification (SRI)
3. Integrated nutrient management (INM)
4. Integrated weed management (IWM)
5. Integrated pest management (IPM)
6. Crop-livestock-fish
7. Crop - tree integration
8. Organic Management
9. Conservation agriculture (CA)
10. Traditional management practices

Additional practices

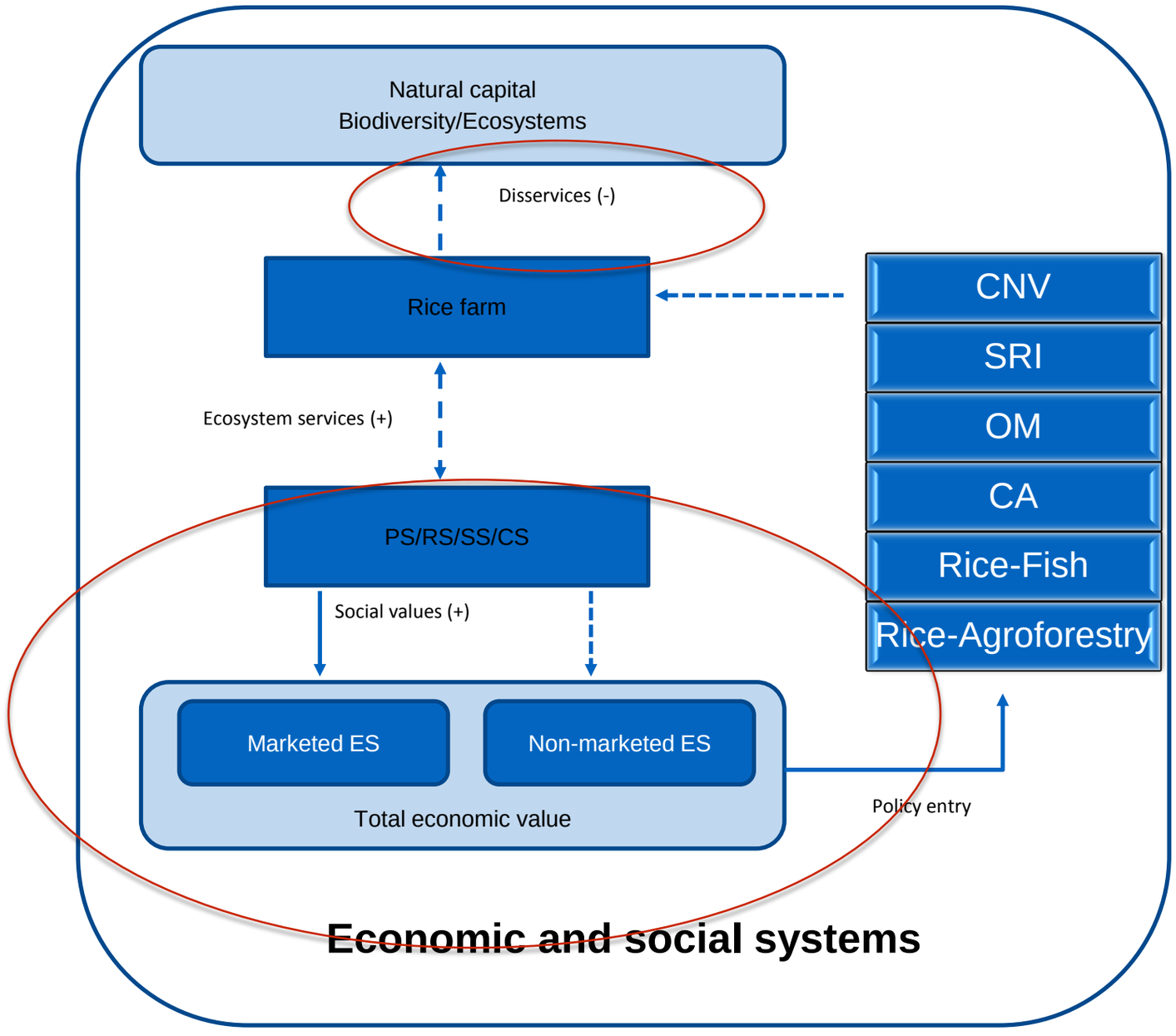
1. Site specific nutrient management (SSNM)
2. Regular monitoring and informed management
3. Conservation of traditional knowledge and management practices

Identify and assess ES in rice agriculture - Philippines

	Conventional Management Practices (CMP/RMP)	System of Rice Intensification (SRI)	Integrated nutrient management (INM)	Integrated weed management (IWM)	Integrated pest management (IPM)	Crop-livestock-fish	Crop - tree integration	Organic Management	Conservation agriculture (CA)	Traditional management practices
Provisioning services										
Food	Rice	Rice	Rice	Rice	Rice	Rice/fish	Rice	Rice	Rice	Rice
Raw material	Rice straw	Rice straw	Rice straw	Rice straw	Rice straw	Rice straw	Rice straw/timber	Rice straw	Rice straw	Rice straw
Genetic resources										Y
Ornamental resources										
Medicinal resources										
Regulating services										
Gas regulation (methane fluxes)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)
Climate regulation	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)
Disturbance regulation							Y (+/-)	Y (+/-)		
Water regulation	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)	Y (+/-)
Water supply										
Erosion control and sediment retention	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

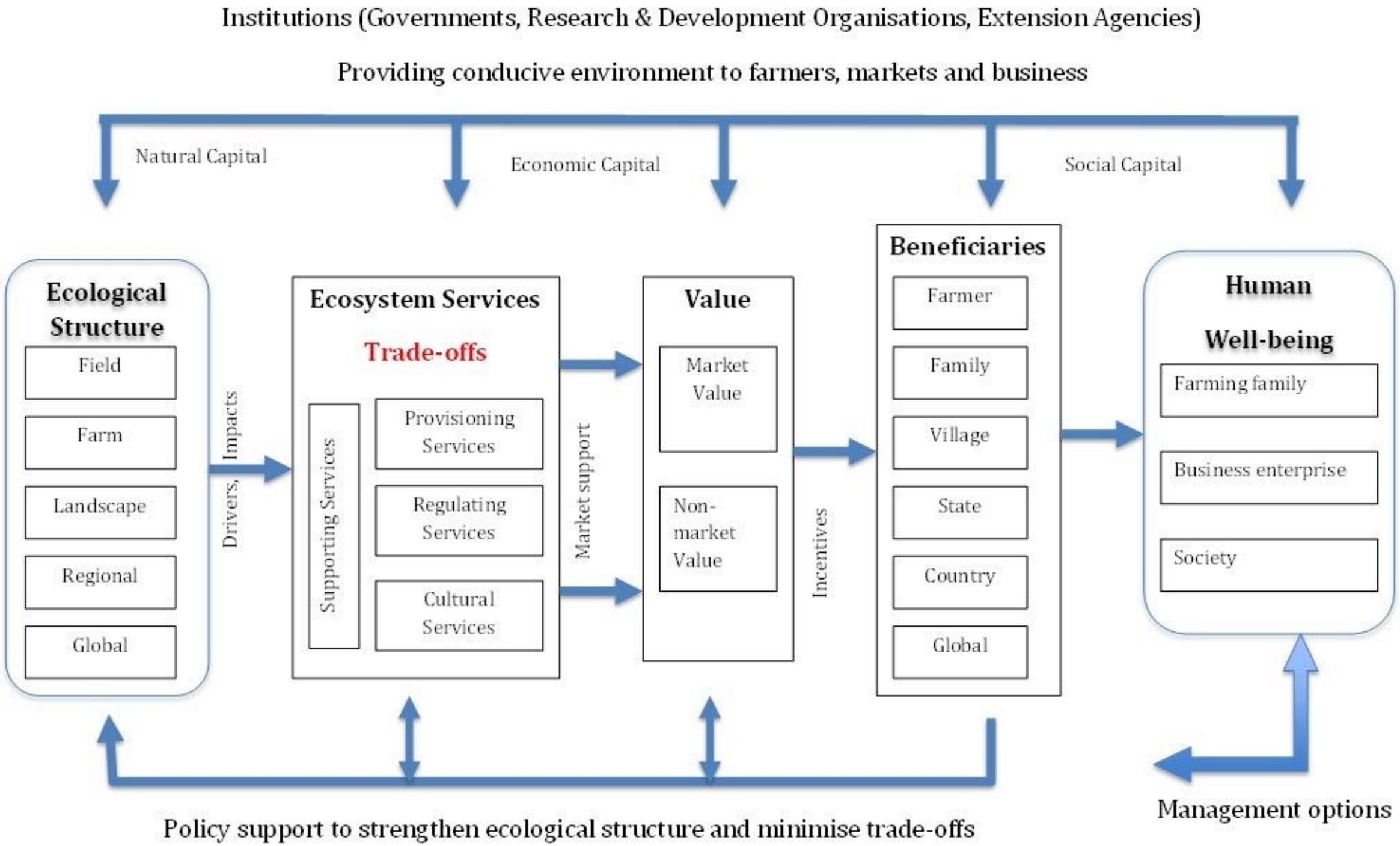
	Conventional Management Practices (CMP/RMP)	System of Rice Intensification (SRI)	Integrated nutrient management (INM)	Integrated weed management (IWM)	Integrated pest management (IPM)	Crop-livestock-fish	Crop - tree integration	Organic Management	Conservation agriculture (CA)	Traditional management practices
Supporting services										
Pollination										
Biological control	Y			Y	Y			Y	Y	Y
Carbon accumulation	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Mineralization of plant nutrients	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Soil formation			Y			Y	Y	Y	Y	Y
Soil fertility	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Nitrogen fixation			Y				Y	Y	Y	Y
Services provided by shelterbelts							Y	Y		Y
Cultural services										
Aesthetics	Y					Y	Y	Y		Y
Recreations						Y	Y	Y		Y
Cultural and artistic information						Y	Y			Y
Spiritual and historic information										Y
Science and education information	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y

Rice Agro-ecosystems



Broken arrow: Invisible value or cost
Solid arrow: Visible value

Framework linking social, natural and economic capital and their interlinkages, underpinned by ecosystem services

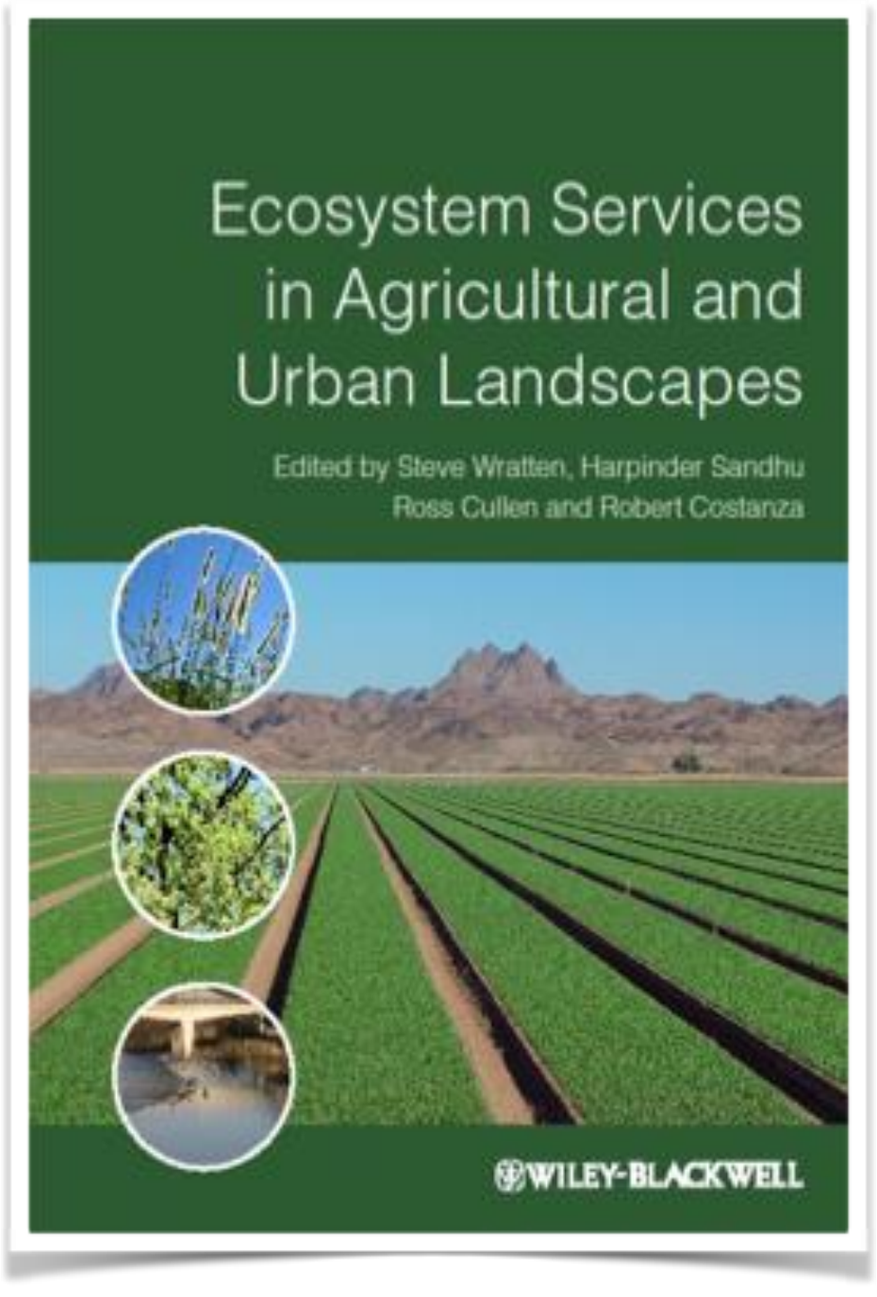


Sandhu 2014 UNEP Report

Two key messages

1. **Bottom-up approach provides more confidence to the ES valuation.**

2. **ES valuation based on biophysical data provides robust evidence for policy options.**



Thank You

Join the community working on ES valuation in agro-ecosystems

- ESP working Group on Agro-ecosystems: http://www.es-partnership.org/esp/81731/5/0/50
- Blog: harpindersandhu.blogspot.com.au
- Twitter:@001harpinder
- Web: http://www.flinders.edu.au/people/harpinder.sandhu