An ecosystem services based analysis of agroforestry systems

Draft findings from valuation study

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Scope of work

- Quantify and demonstrate potential of Agroforestry to deliver Provisioning and regulating ecosystem services
- Economic valuation of ecosystem services in three agroforestry systems in SSA:
  - Moderate and heavy shade cocoa AF in Ghana
  - Semi-forest and home-garden coffee in Ethiopia
  - *Ngitili* (rotational grazing exclosures) in Tanzania
- Recommend Policy and incentive approaches for promoting AF in productive Lived-in landscapes and potential for fostering REDD+ payments

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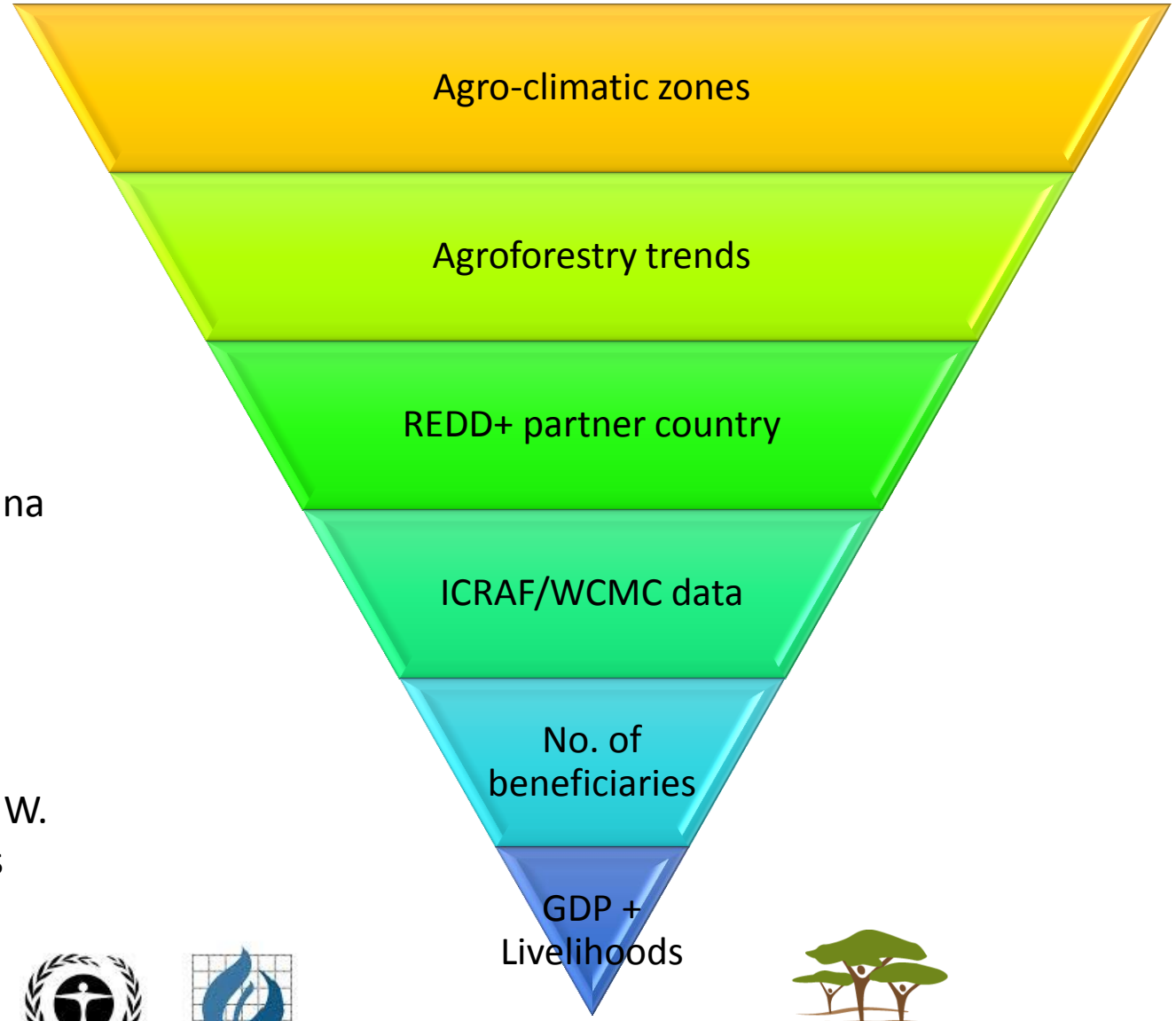
Case study selection

- Multiple criteria for screening case studies
- Potential for estimating visible and 'invisible' (regulating, habitat & biodiversity) ecosystem goods and services (EGS)
- **Three Systems**
  - Moderate and heavy shade cocoa AF in Ghana
  - Semi-forest and home-garden coffee in Ethiopia
  - *Ngitili* (rotational grazing exclosures) in Tanzania
- Coffee in 23 countries across several agroecosystems; Cocoa in 11 countries largely in W. Africa and Congo Basin; & Ngitili in five countries



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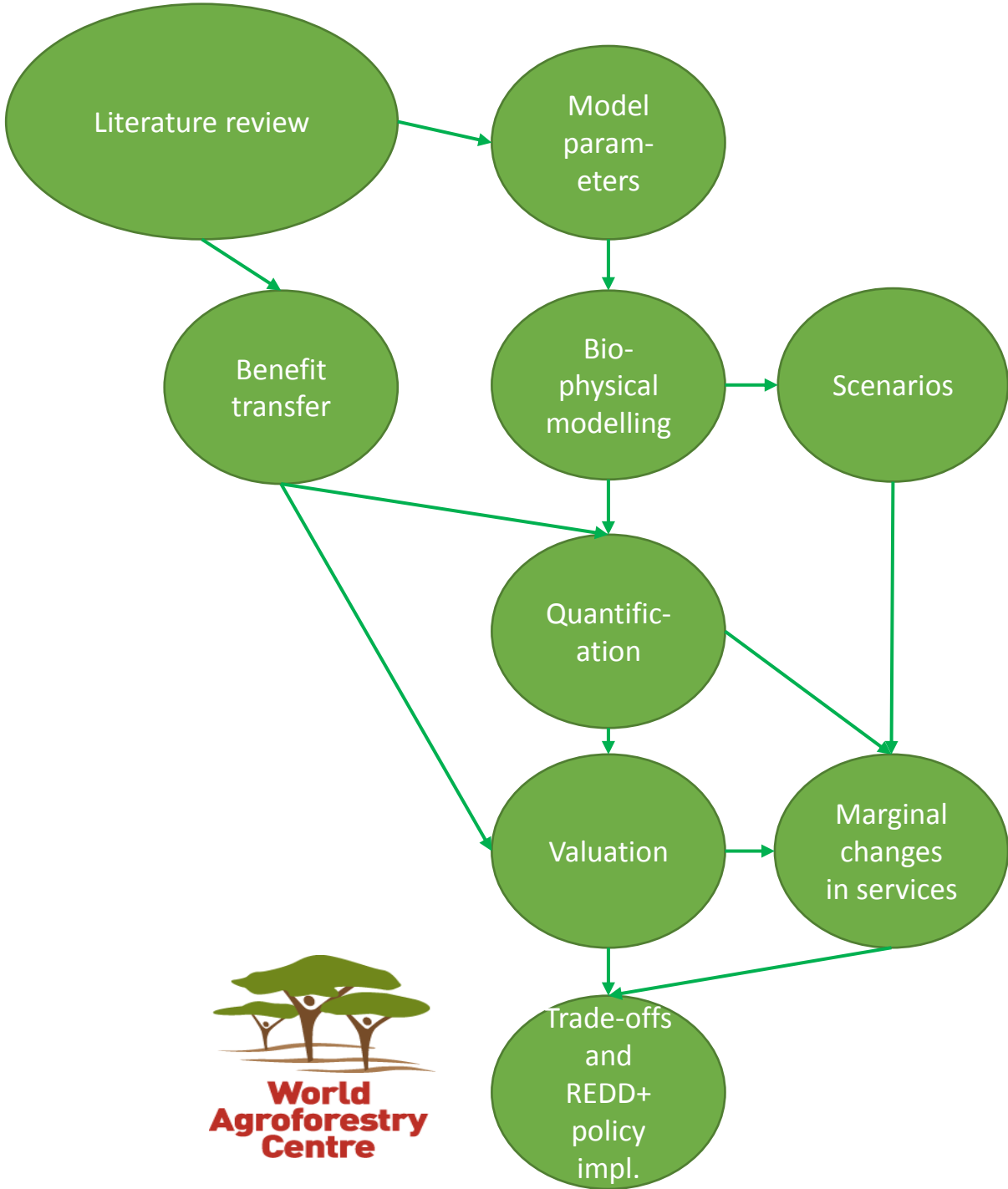
Quantification and valuation process

- LARGELY BASED ON LITERATURE REVIEW
- EGS quantification via literature review estimates and benefit transfer
- Literature review also used for model parameterization (eg. % canopy cover)
- Services modelled (quantified) in scenarios analysis based on hydrological model (WaterWorld) and regression equations
- Economic valuation for estimated and modelled EGS quantities via benefit transfer methods
- Analysis of marginal changes in services; trade-offs and REDD+ policy implications



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Services Investigated

Monetized services

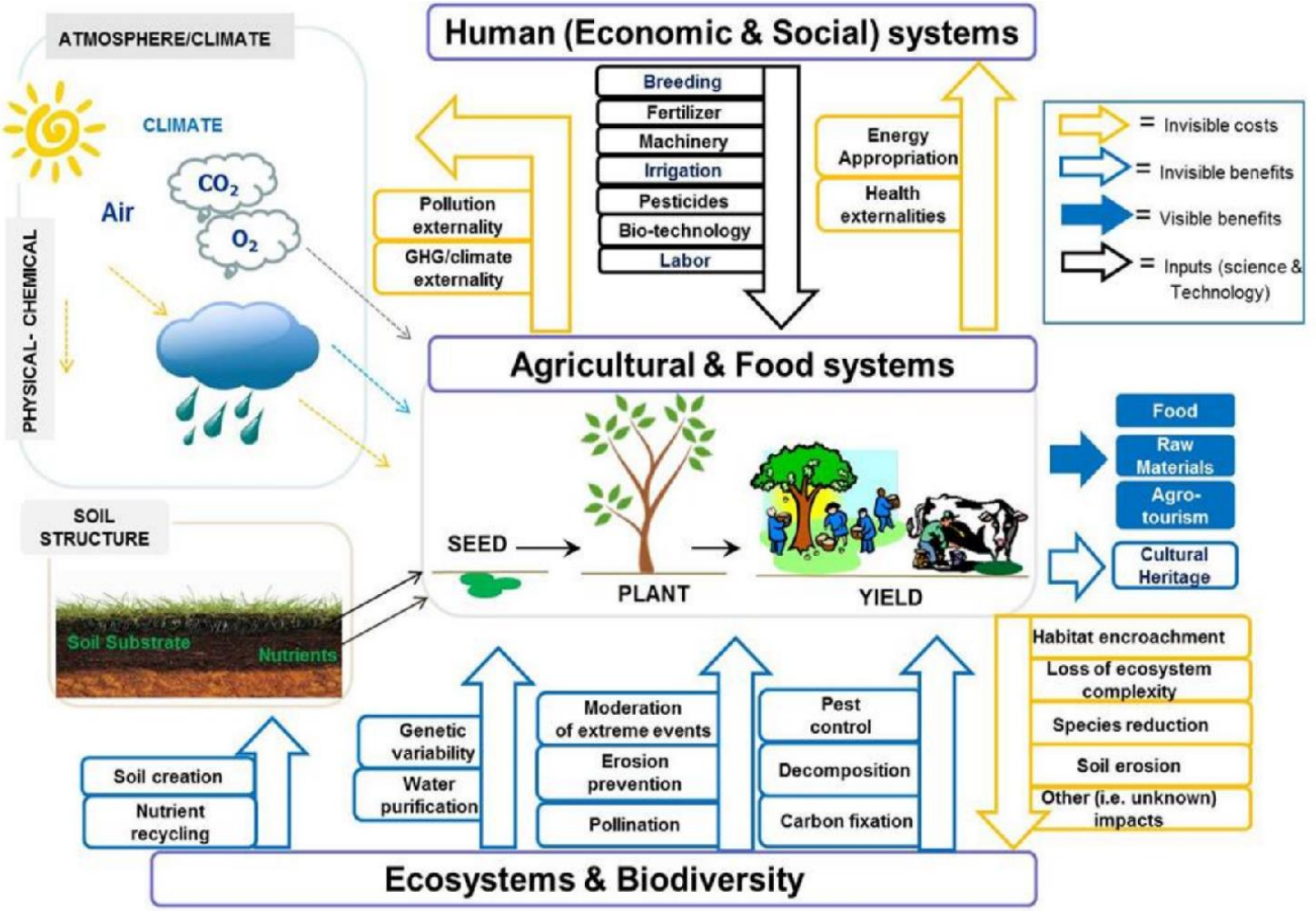
- Provisioning (food and cash crops, timber, biomass energy, bush meat, fodder, medicinal plants, other NTFP)
- Above & belowground biomass C stocks, soil C stocks
- Water provisioning
- Soil fertility (N,P, K nutrient stocks) – Tanzania only
- Erosion control - Ethiopia and Tanzania only

Quantified Services

- Water quality
- Biodiversity (on-farm and landscape)
- Erosion control
- Soil fertility and nutrient cycling - Ghana (agroforestry only)

Investigated but not quantified or monetized

- Pollination
- Biological pest control
- Moderating extreme weather events



Source: Hussain and Miller (2013)

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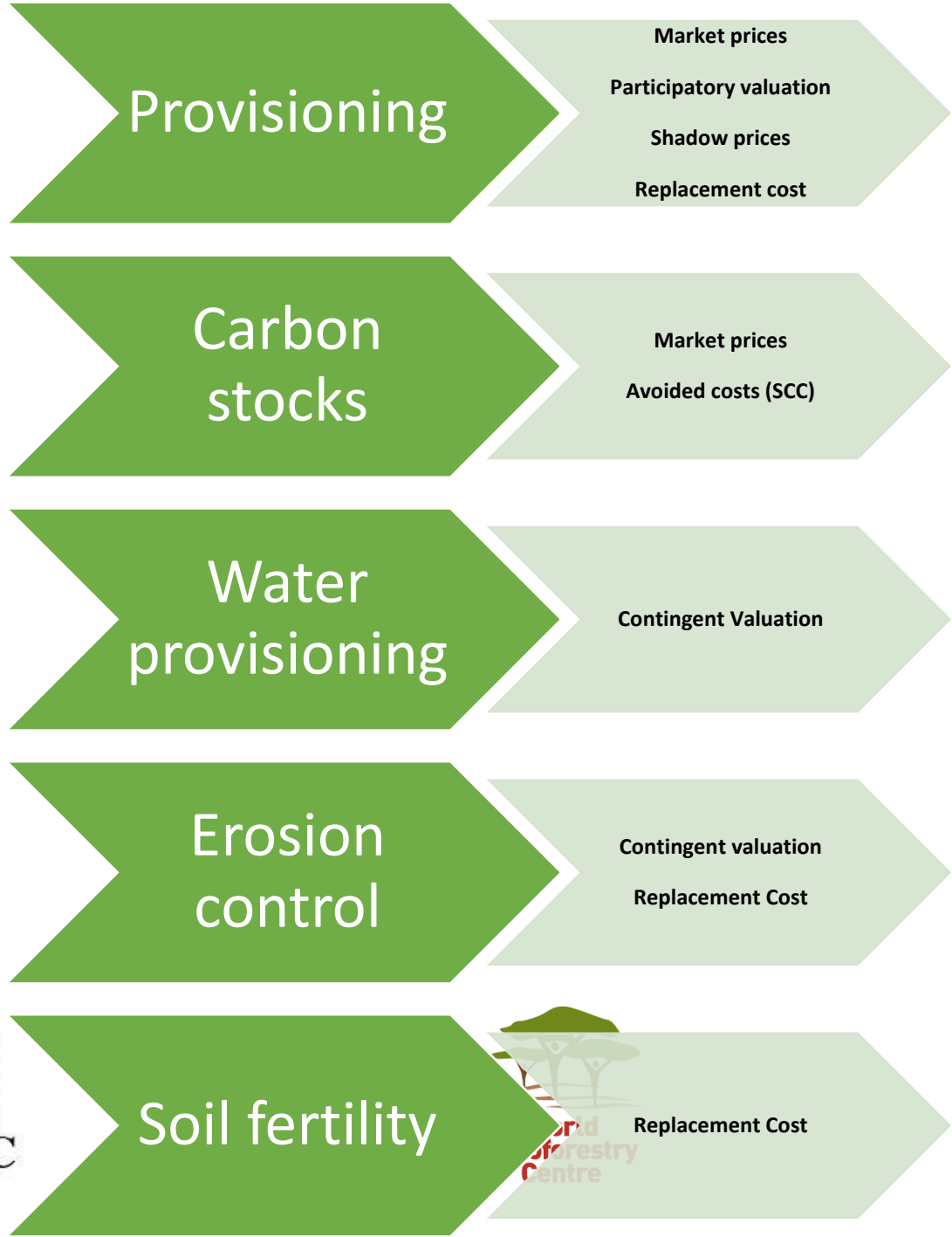
Valuation methodology

- Very few monetizable estimates of regulating services
- Difference in carbon stocks divided over 25-year period to approximate performance based REDD+ payments
- Low CO_2 price ($6.5/tonne) – agriculture & agroforestry-based offsets in SSA (Ecosystem Marketplace 2013)
- High CO_2 price ($40/tonne) – social cost of carbon (US-EPA 2013)
- Asset values of each land use computed via NPV (discount rates of 7.5%, 10%, 20%) and BCR over a 20-year time horizon



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Scenarios analysis: methods

- Scenario development: baseline, conversion and extension
- Modelling: Geospatial, WaterWorld Model, sub-basin level

Scenarios:

- *Baseline*: ecosystem services in target system in current state (all countries)
- *Increase of % (shade) trees cover* in the existing system (all countries)
- *Expansion of agroforestry* into all areas currently under other cropping or grazing (Ethiopia and Tanzania)
- *Reverse* scenario: all areas currently under agroforestry turned into monocultures (all countries)

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Methodology: limitations

Valuation

- Small datasets (*n* per service per system = 1-5)
- Physical quantities and/or monetary values not always measured consistently
- Absence of comparators or non-identical comparators
- Scaling to basin and regional levels can amplify error

Scenarios

- Inconsistency in definitions/classification systems (tree and canopy cover)
- Lack of established relationships between data used or produced by models with biophysical characteristics of the systems
- Lack of spatial data on agroforestry systems
- Inherent complexity of agroforestry systems makes them difficult to model

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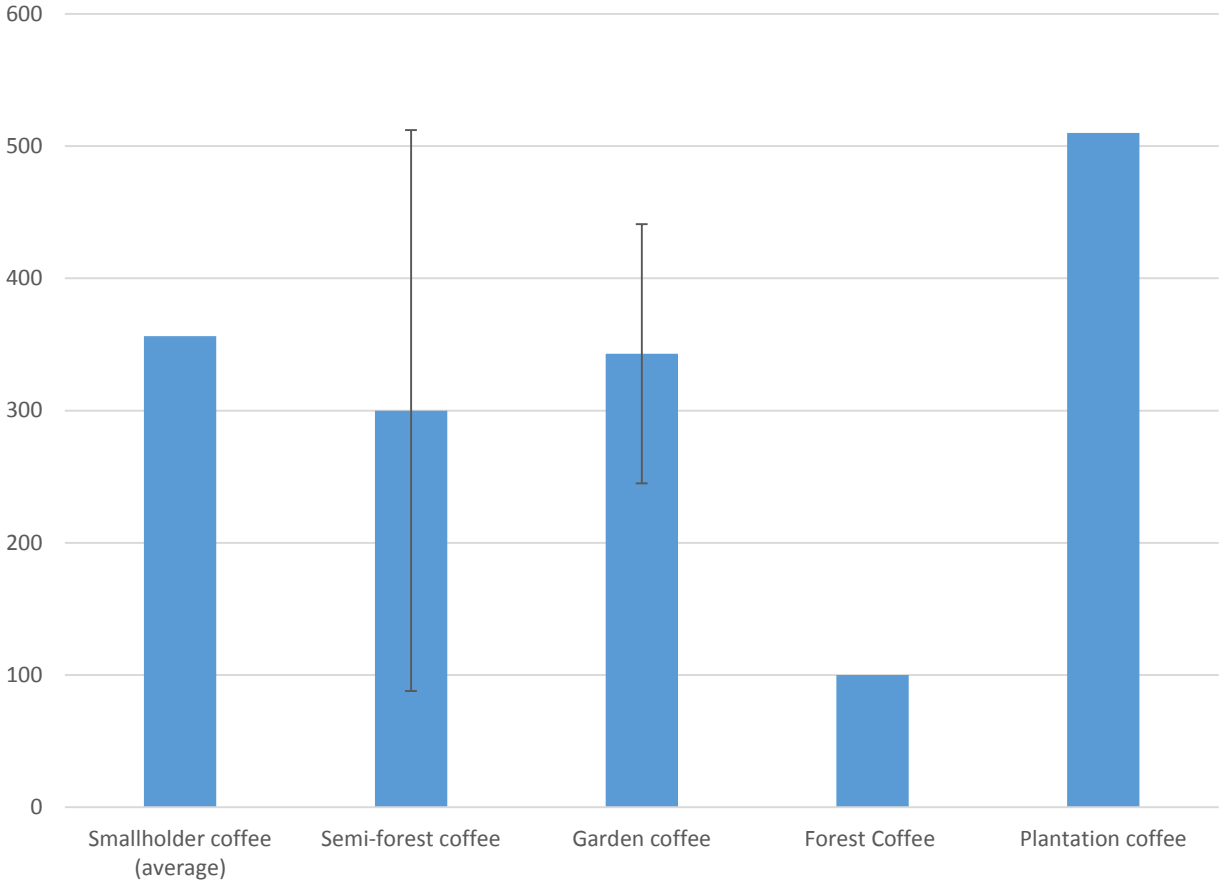
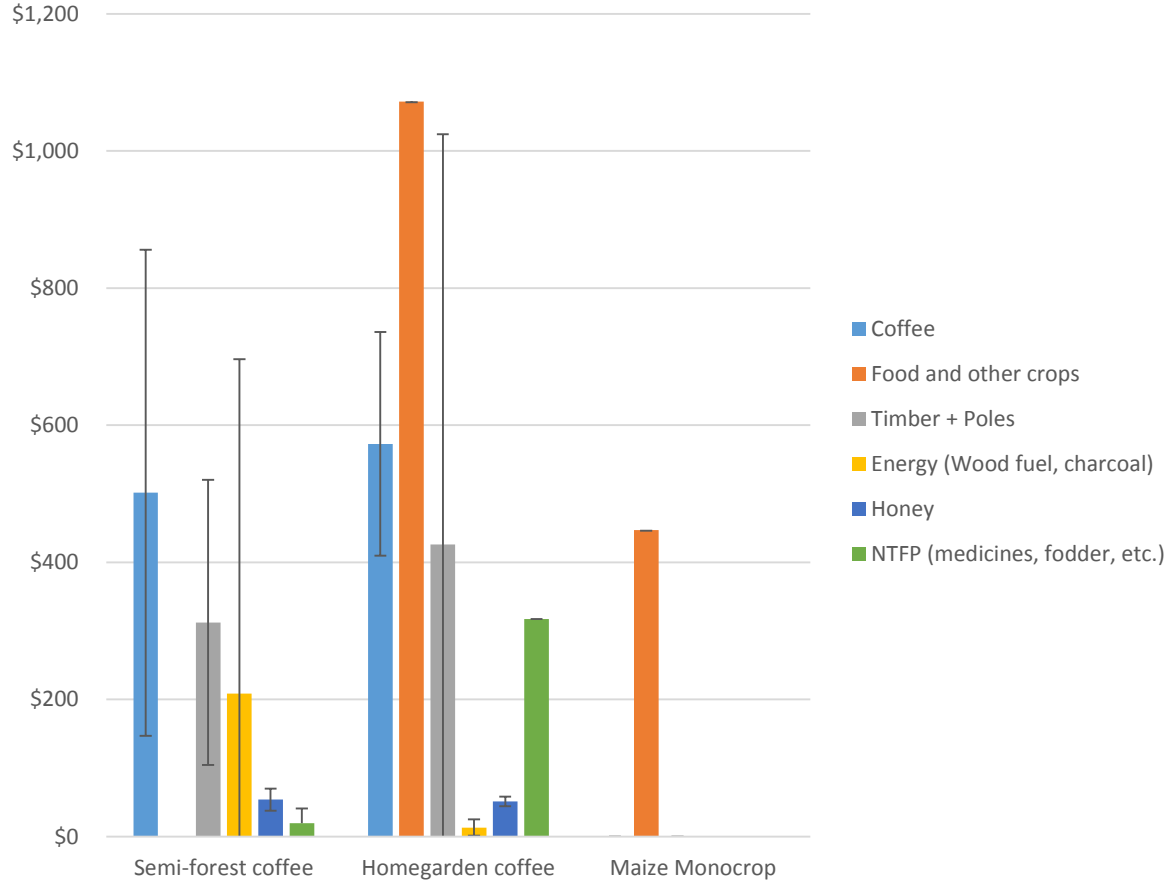
Example: coffee agroforestry provisioning services

Yields (kg/ha)



- Large variation in yields within and between systems

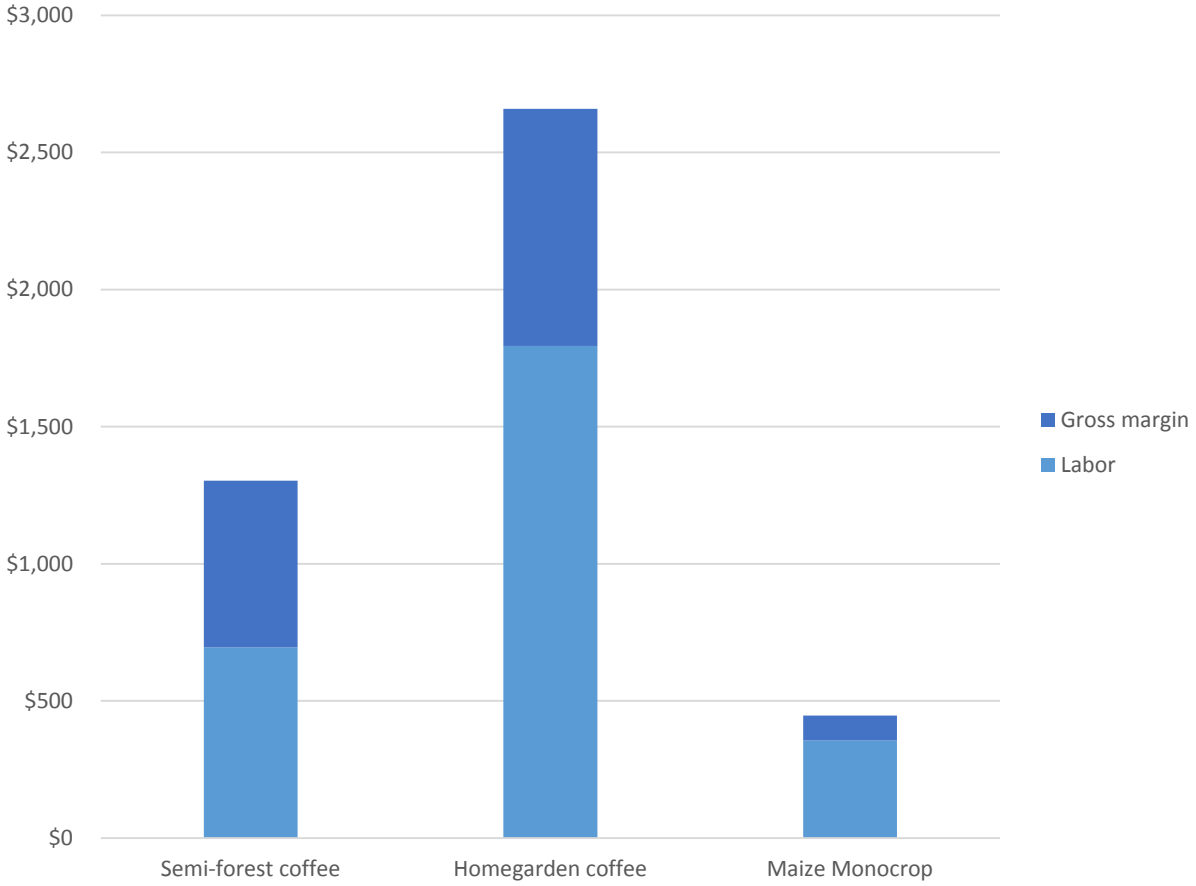
Monetary Values ($/ha)



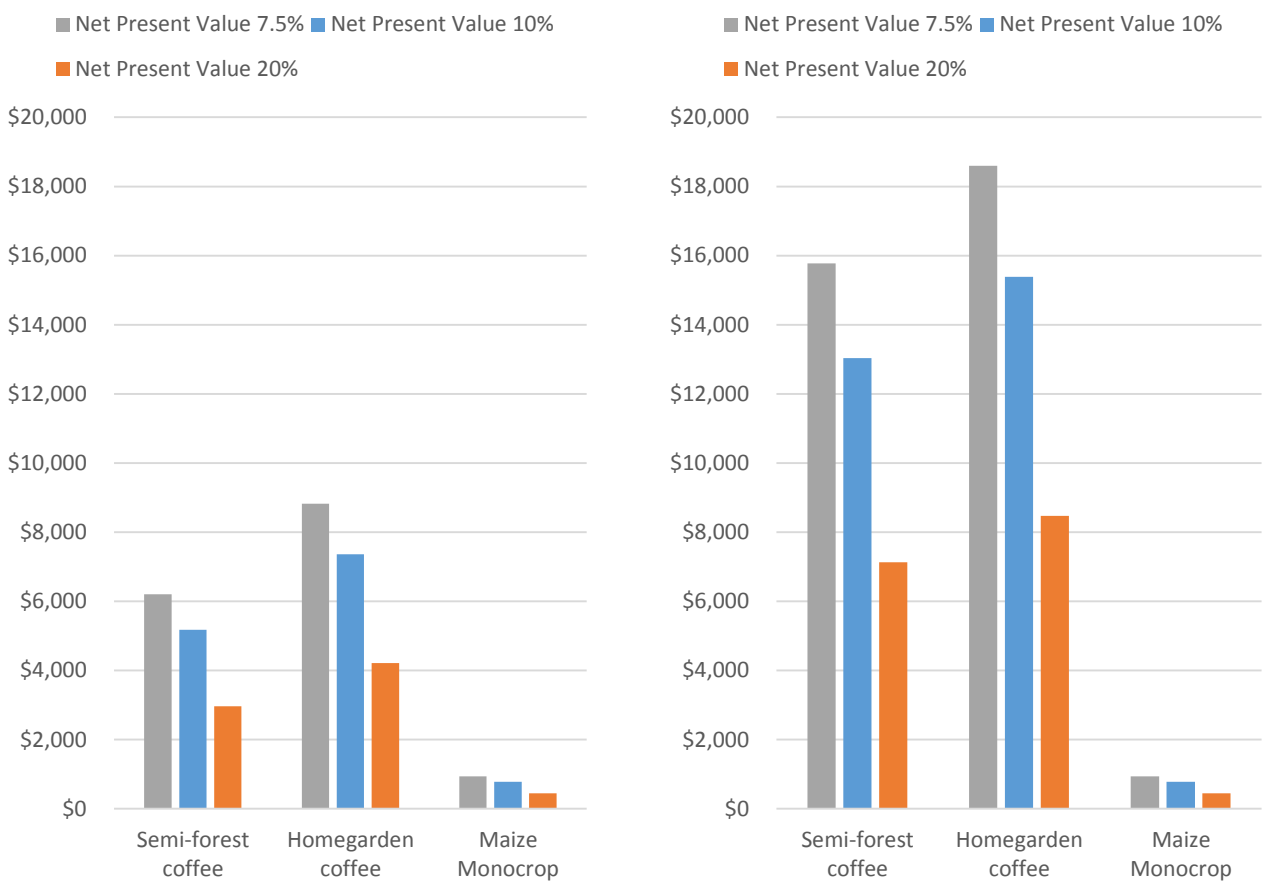
- Semi-forest coffee more specialized, garden coffee more diversified

Example: coffee agroforestry gross margin and NPV

Labor costs and gross margin ($/ha)



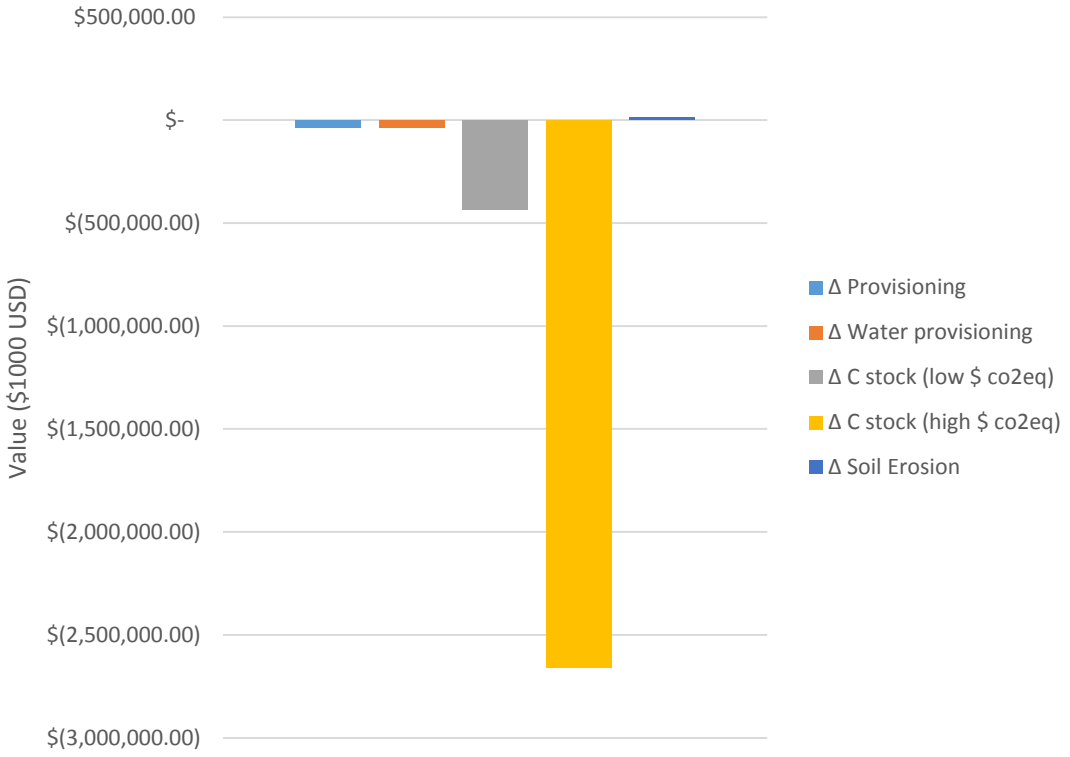
NPV/ha low and high carbon prices



- Very few synthetic inputs used in Ethiopian coffee systems, and organic inputs could not be costed
- Garden coffee appears to have higher gross margin and NPV

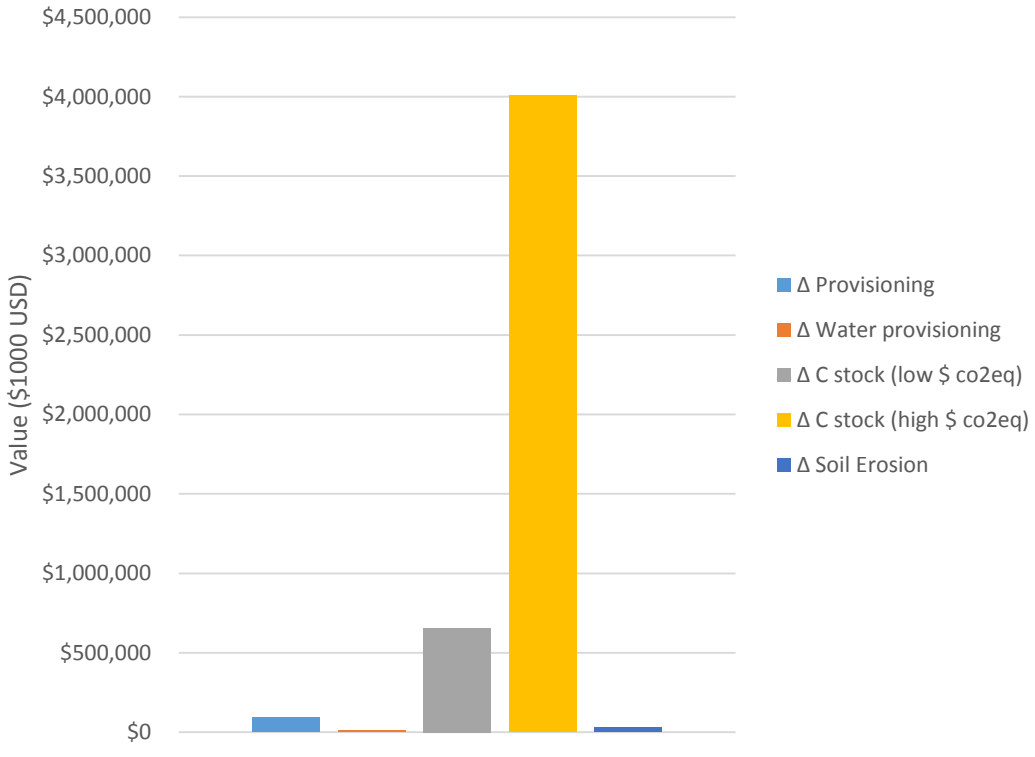
Example: coffee agroforestry scenarios

Scenario 1 (Coffee agroforestry to monocrops)



- In keeping with biophysical results, largest changes in economic values for both scenarios are for C stocks

Scenario 3 (Monocrops to coffee agroforestry w/enhanced shade)



- Despite significant biophysical changes, using the only retained valuation study suggests that monetary values (via WTP) of gains and losses in soil erosion are modest

Towards an agroforestry EGS research agenda

Valuation

- Further quantification & valuation of negative externalities, as well as regulating & habitat/biodiversity services
- Harmonizing comparators & metrics
- Spatially explicit, landscape approach
- Analyzing trade-offs among services, and among monetary & resilience values
- Assessing C stocks at greater soil depths (eg. 30-50 cm)

Scenarios Modelling

- On the ground or expert-opinion based mapping to support more accurate scenario modelling
- Higher resolution RS and newer techniques
- Use of back-casting techniques to identify factors that may support change under different scenarios

Source: Circle2

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Modelled scenarios

	Scenario 1	Scenario 2	Scenario 3
Cocoa Agroforestry, Ghana	Full sun/lightly shaded. Tree cover* max 30%	Increased shade system. Tree cover* between 30% and 84%	
Coffee Agroforestry, Ethiopia	Conversion to maize mono cropping. Tree cover max 5%	Full shade system. Tree cover minimum 60%	Full shade system as scenario 2 but extended into areas suitable but currently not agroforestry
Ngitili Agroforestry, Tanzania	Conversion to maize mono cropping. Tree cover max 1%	Extended *ngitili* system into areas suitable but currently not AF. Tree cover minimum 20%	
* Combination of cocoa and shade trees			

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Scenarios analysis: results

- Main changes under studied alternative scenarios:
  - Carbon
  - Soil erosion

- Water quality mostly impacted under monocropping systems: generally improves with increased tree cover

- Water quantities:
  - Small changes
  - Direction of change depends on water use of different vegetation types
  - Water use can be higher under monocropping
  - Impacts on seasonal distribution of water flows not assessed, but likely significant

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Valuation methodology

- Distinguishing intermediate and final services
- Only provisioning services, carbon valued additively in CBA
- Estimated gross margin of coffee and cocoa agroforestry vs. comparators
- Gross output values estimated for *ngitili* due to lack of data on labor costs
- Simplified model of life cycle of cocoa production system; coffee and *ngitili* modelled at maturity

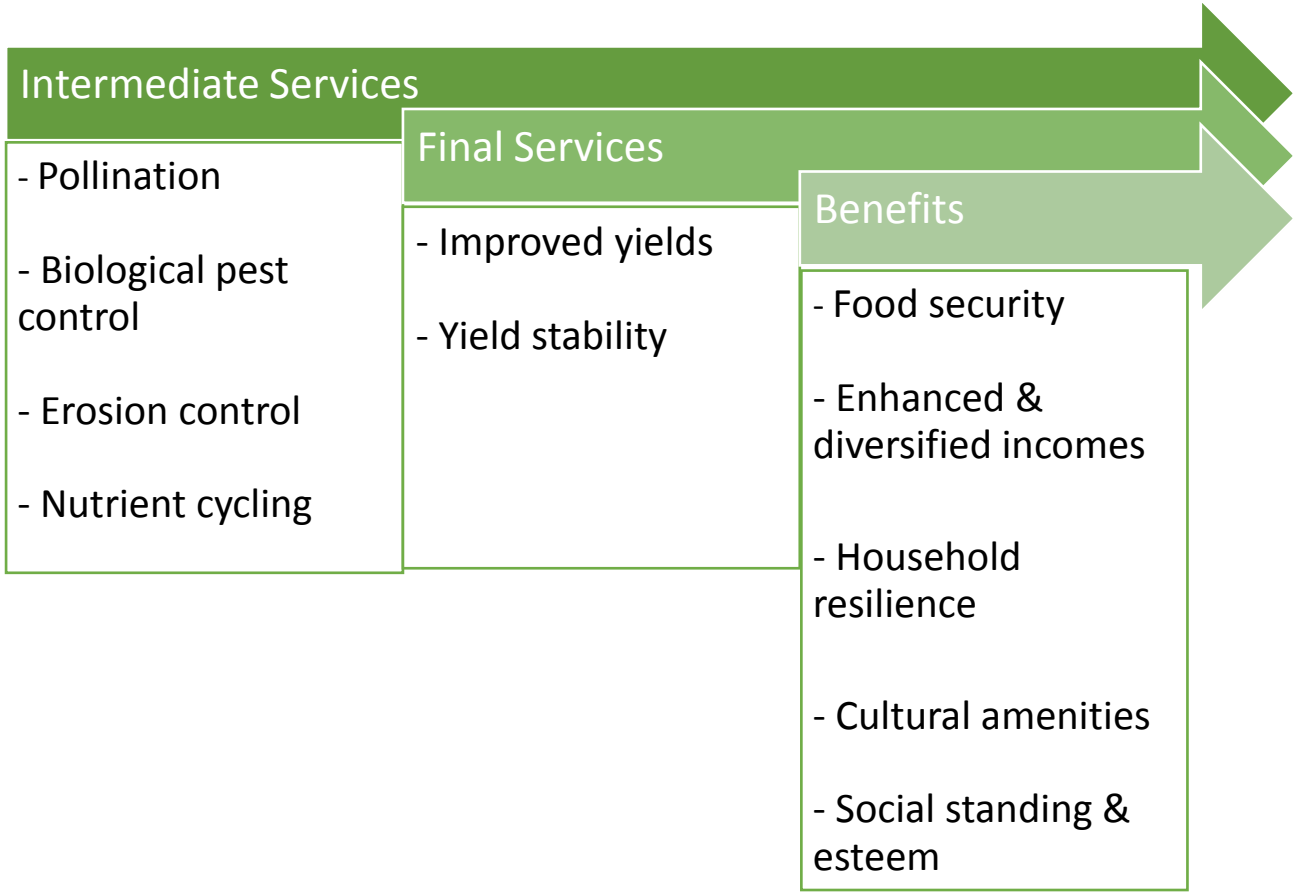

Diagram adapted from Fischer et al. 2009

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Valuation results

- Contribution of in-situ C stocks to overall economic values per ha is modest
- Food security outcomes enhanced by all three agroforestry systems
- Low sensitivity of dominant systems to discount rates and to carbon prices
- In the case studies, few trade-offs between income and regulating EGS
- Highest trade-offs between income and EGS in Ghana

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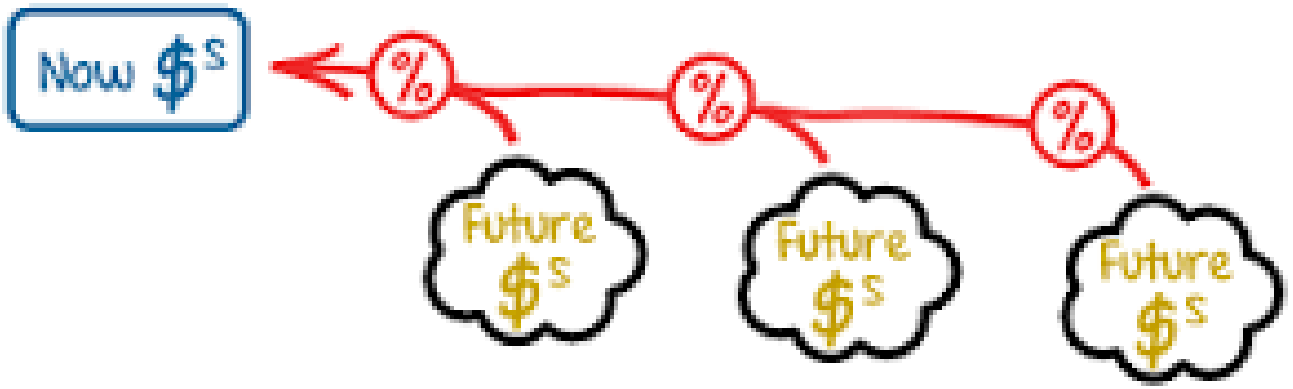
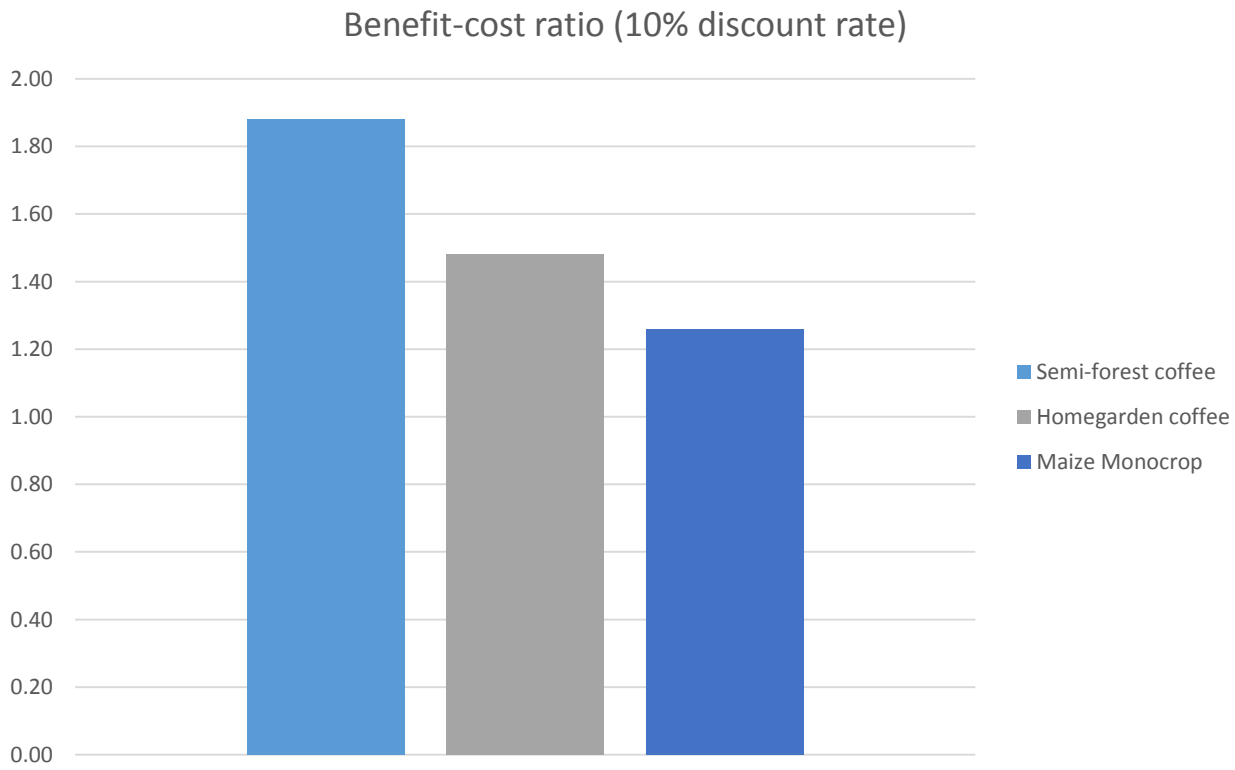
Discount rates and BCR

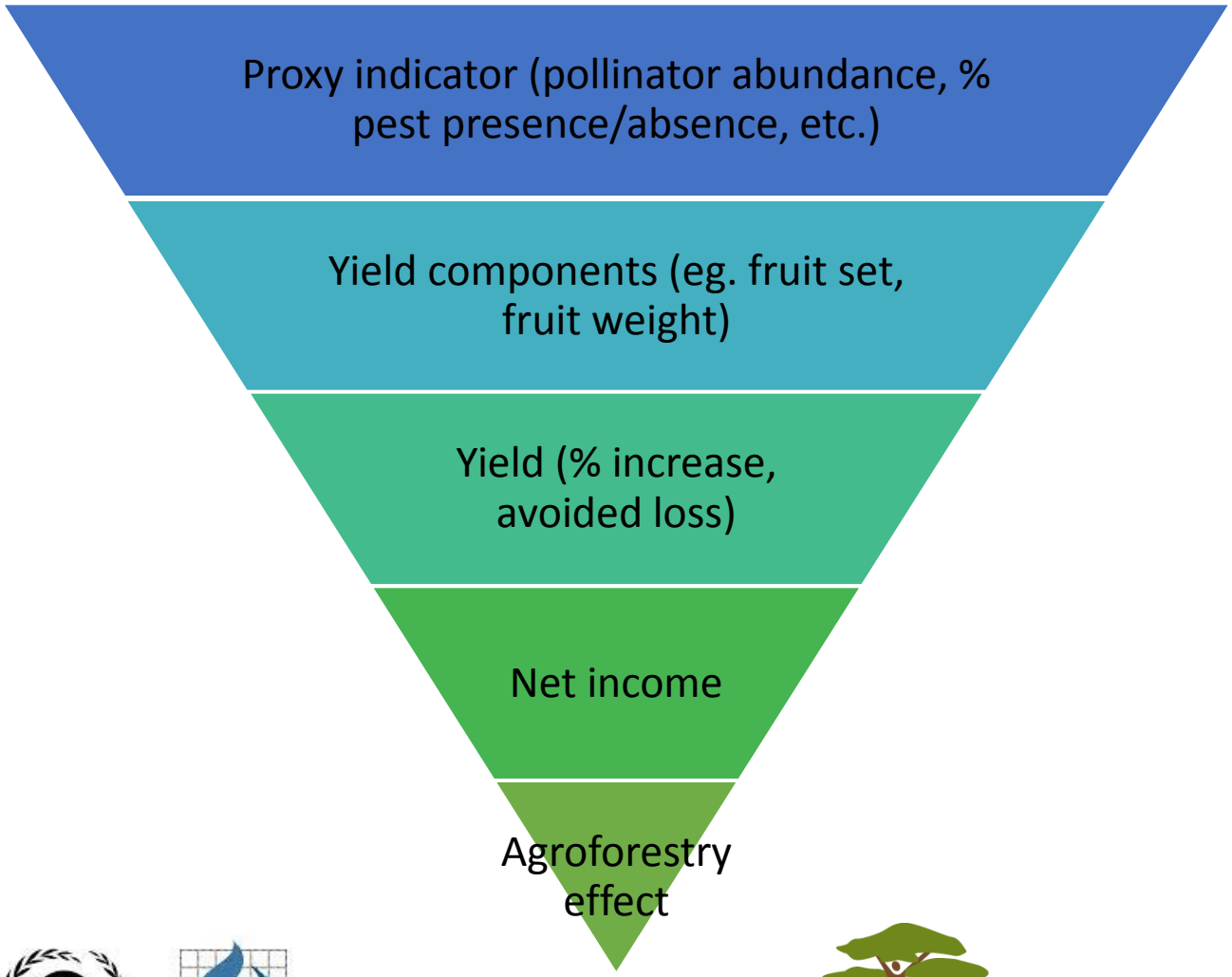


- 7.5% discount rate close to estimated lower-bound opportunity cost of capital in developing countries (Gockowski et al. 2011)
- 10% discount rate
  - In line with previous CBAs in Tanzania, Ghana, Ethiopia (e.g. Monela et al. 2005; Obiri et al. 2007; Asare et al. 2014; Reichuber et al. 2012).
  - Used by World Bank to estimate opportunity cost of its loanable funds (Asian Development Bank 2007).
- 20% discount rate an expert estimate of time value of money in Ghana (eg. Gockowski et al. 2013)



Pollination and biological pest control studies

- Dearth of studies in sub-Saharan Africa
- No rigorous assessment of economic value of wild pollination for cacao
- Most studies worldwide only examine proxy indicators or yield components
- Replacement cost estimates not possible due eg. to lack of commercial pollinator markets in case study countries
- Economic effects of wild pollination or biological pest control in coffee and cocoa systems often insensitive across land use and land intensification gradients *(*eg. Kellerman et al. 2008*;* Classen et al. 2014); thus not an explicit agroforestry effect



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Select biodiversity values

Ethiopia

- Hein and Gatzweiler (2006): breeding and extension program for improved coffee varieties from wild Ethiopian Arabica coffee has an NPV of approximately USD 420 million at a 10% discount rate over a 40-year period.
- No significant difference in understory avian species diversity (Shannon Index) in coffee AF compared to natural forest ((Buechley et al. 2015); approximately 58% of bird species were shared between coffee AF and forest plots (Gove et al. 2009)

Ghana

- Bia Conservation Area and Kroshua hills Forest Reserves in Western region of Ghana have high biodiversity significance:
  - Important habitat for the Roloway Guenon (*Cercopithecus diana roloway*) and the white-naped mangabey (*Cercocebus atys lunulatus*), two of the most highly endangered primate species in Africa (Oates 2006; Asare et al. 2014)
  - Threatened by extensive forest clearing for cash crops (eg. cocoa, oil palm) (Gockowski et al. 2011)
- Moderate shade cocoa agroforests have approximately 77% of the bird species found in remnant forest, whereas full sun only has 32% of forest bird species (Asase et al. 2005)
- Shaded cocoa forests have approximately 60% of vegetation species found in remnant forest whereas full sun cocoa only has around 8% of remnant forest vegetation species (Asase et al. 2005)

Tanzania

- No significant difference in terms of H' and C' diversity indices for herbaceous species across *ngitili* of different age and tenure status, as well as compared to communal grazing land (Selemani et al. 2013)
- By late 1980s, 145 bird species observed in ngitili managed areas; H' values of 2.14 - 4.28 depending on district (Monela et al. 2005)

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Erosion control and maintenance of soil fertility

- High-level, national scale assessments of costs of soil erosion undertaken in all three countries by eg. World Bank, IFPRI
  - Typically valued via estimated yield penalties for staple crops
  - Little quantification of downstream costs and benefits of soil runoff and re-deposition
  - Erosion control values estimated for Ethiopian case study via contingent valuation (Gebremariam et al. 2013)

- Soil fertility (N,P,K stock) estimates complicated by:
  - Absence of data on relevant comparators (eg. monocrops, full sun cocoa, full sun coffee)
  - Accounting for differences in soil characteristics between agro-ecological zones
  - Incomplete data (eg. reporting % N but no data collected on soil bulk density)
  - Consistent data only available for Tanzania case study, valued using replacements costs of urea & NPK (17-17-17) fertilizers

Soil N,P,K stock values: Tanzania