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Forest Carbon Measurement: Review of Methods and Potential Role of Remote Sensing and GIS for Successful REDD Implementation

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Introduction

Climate Change: A serious global threat

Observed effects of climate change

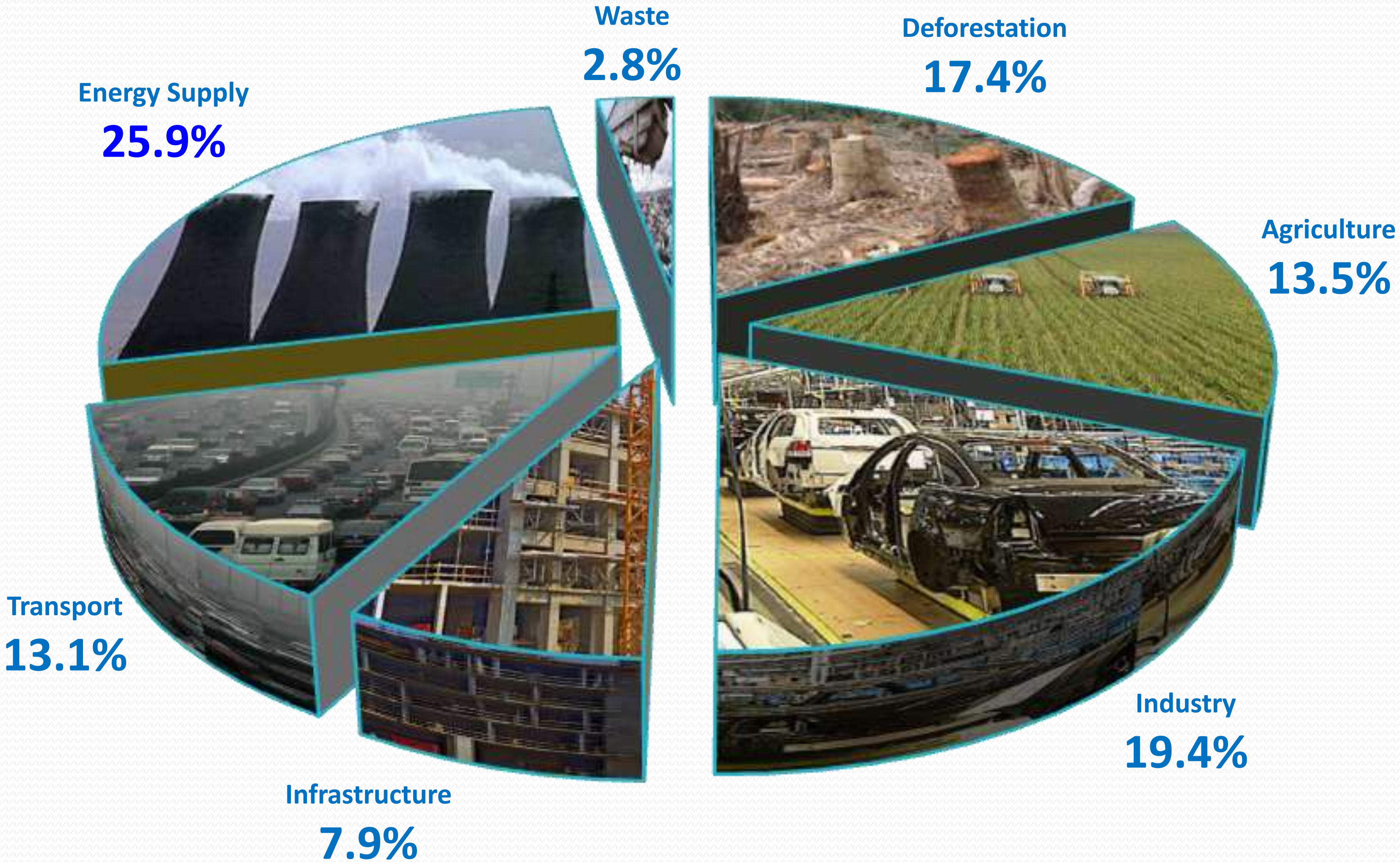
- Warmer water and more hurricanes
- Ice and snow - melting
- Sea level - rising
- More drought
- Economic and human loss

Climate change - mainly because of rising atmospheric temperature

- **The mean atmospheric concentration of CO2**
  - **Pre-industrial period - nearly 280 ppm**
  - **Recently – about 384 ppm**
  - **Increased 100 ppm = 160 billion tonnes of CO_2 , 30% overall increase**
  - **If reached 550 ppm, 50-75% forest will be disappeared**

Source: Maslin (2009)

Sources of emissions



Source: IPCC, 2007

Forests role in Global Carbon Budget

- **Reservoirs** - **more than double of atmospheric CO_2 .**
- **Sinks** – **growing forests accumulate CO2**
- **Sources** - **Forests are burnt or cut, CO2 is released**

Forests in the present climate regime

- **Despite the importance of natural forests, afforestation and reforestation (sinks) activities are only eligible in CDM-Kyoto**

The new agenda – under consideration in UNFCCC RED/REDD / REDD Plus

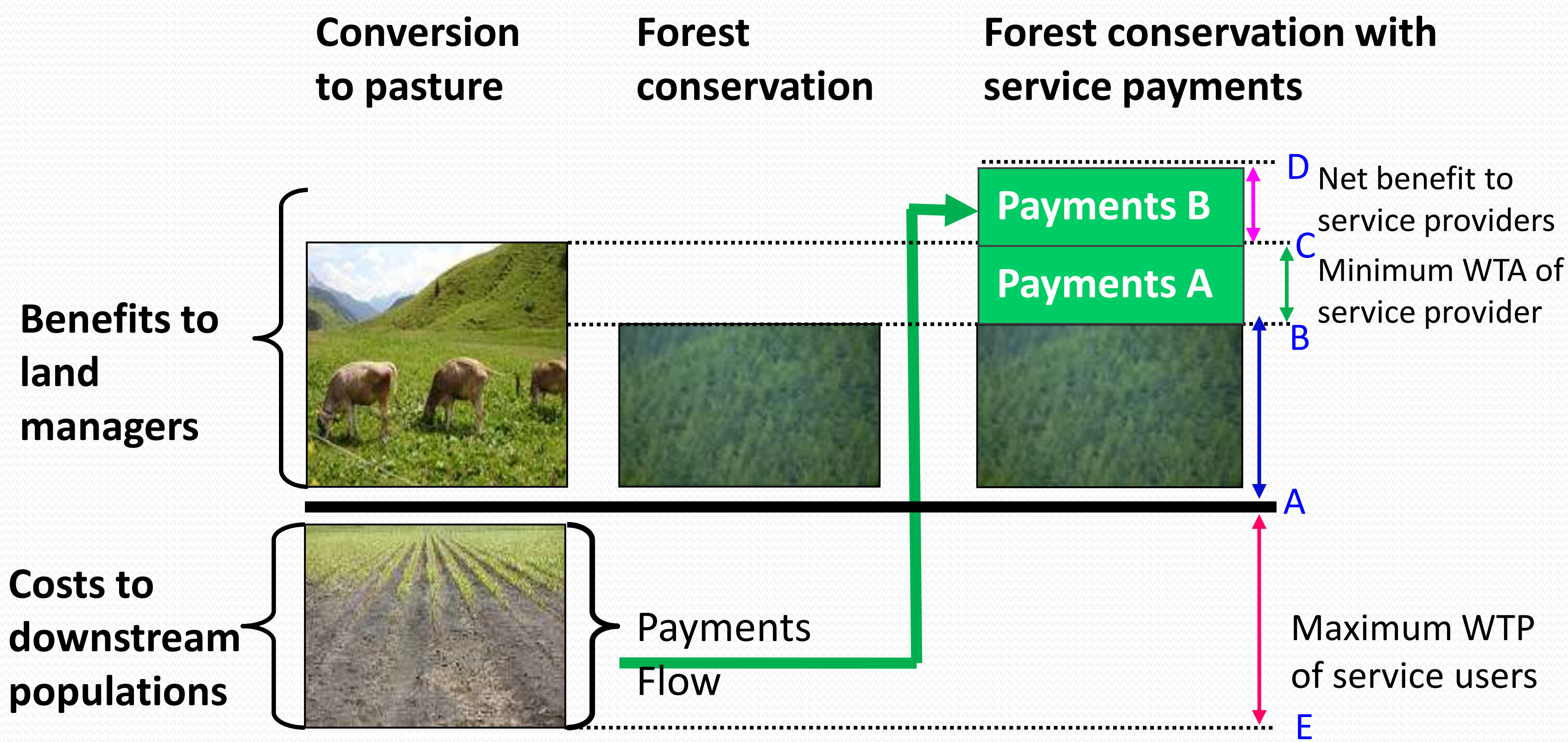
RED - Reduced Emission from Deforestation (also known as avoided deforestation)

REDD - Reduced Emission from Deforestation and Forest Degradation

REDD Plus is avoided deforestation as well as forest enhancement (co-benefits)

The concept of PES

PES: **Mechanisms though which beneficiaries of the ecosystem services pay the service providers cash or in-kind**



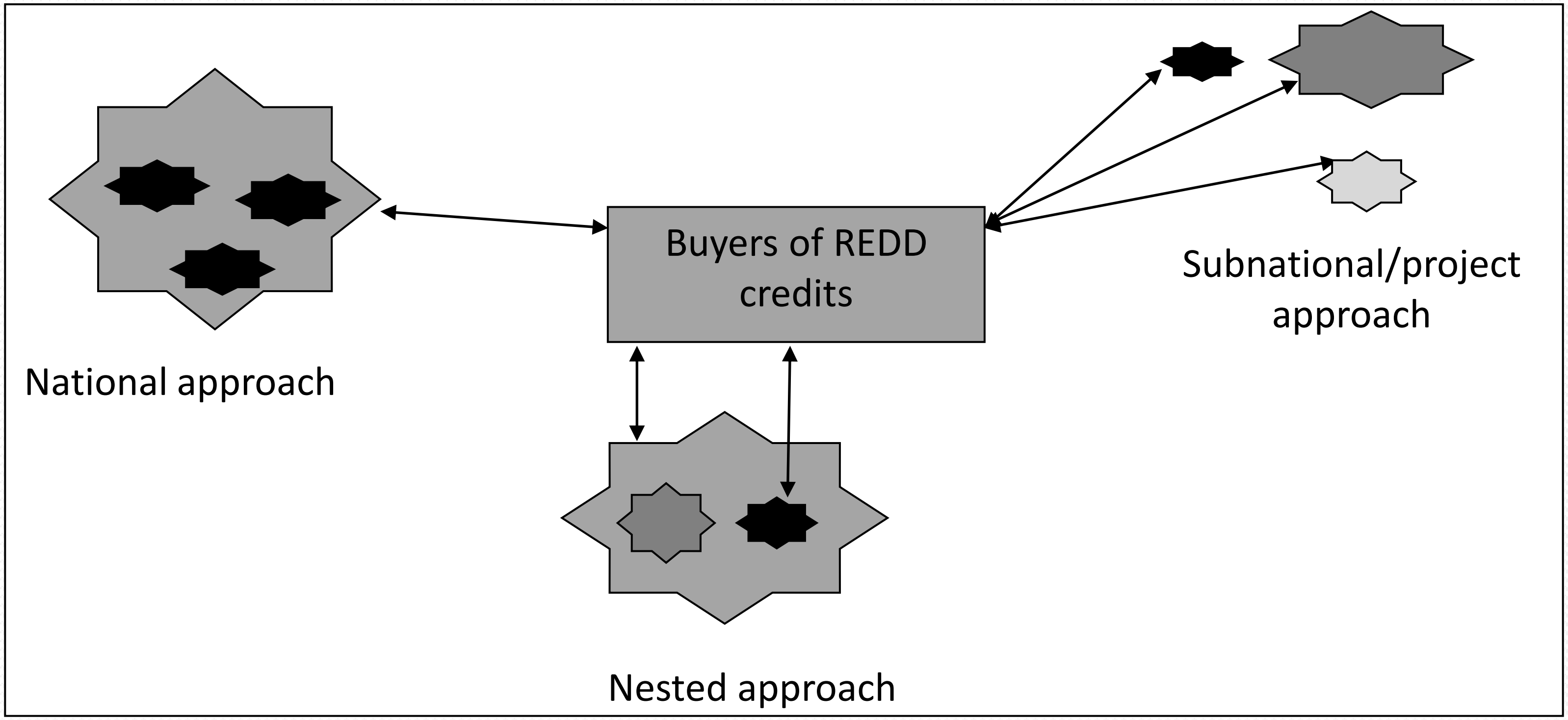
(Adapted from Pagiola et al., 2003)

Land cover change before and after community forestry programme (Nambu, Nepal)

In 1978

In 2005

Potential geographical scales of REDD accounting and crediting



(Source: Adapted from Angelsen, 2008)

- One of the major challenges is for MRV

Monitoring deforestation and forest degradation

Monitoring and verification for REDD requires five different sets of data:

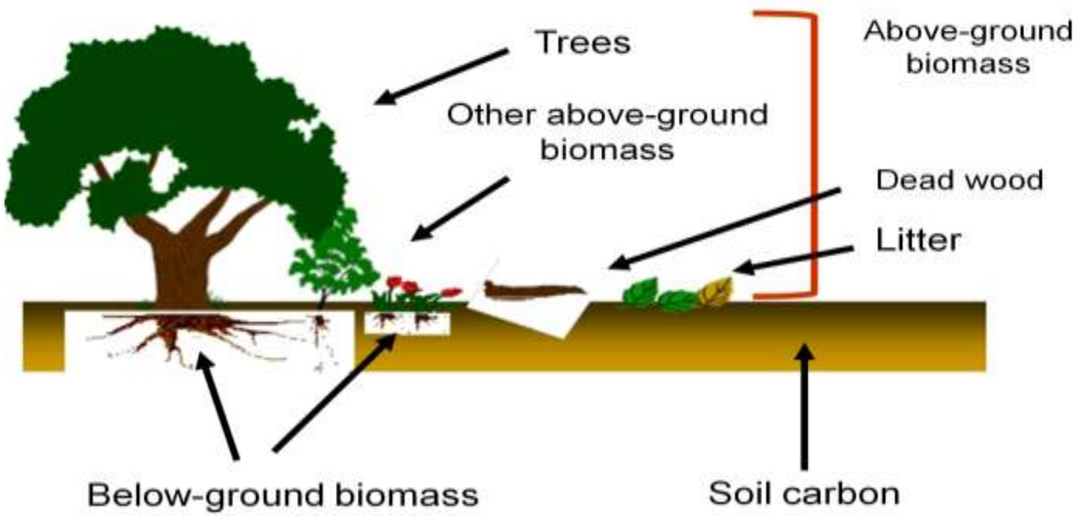
- The aerial extent of deforestation and forest degradation in hectares,
- The location of the deforestation or forest degradation losses occurred (in what forest type),
- The carbon content of each forest type in tonnes per hectare,
- The process of forest loss which affects the rate and timing of emissions.

Ramankuttty et al. (2007),

Estimating forest carbon stock

Define the carbon pools to be measured and monitored

- Possible carbon pools
  - Above-ground biomass
  - Below-ground biomass
  - Dead wood
  - Litter
  - Soil carbon

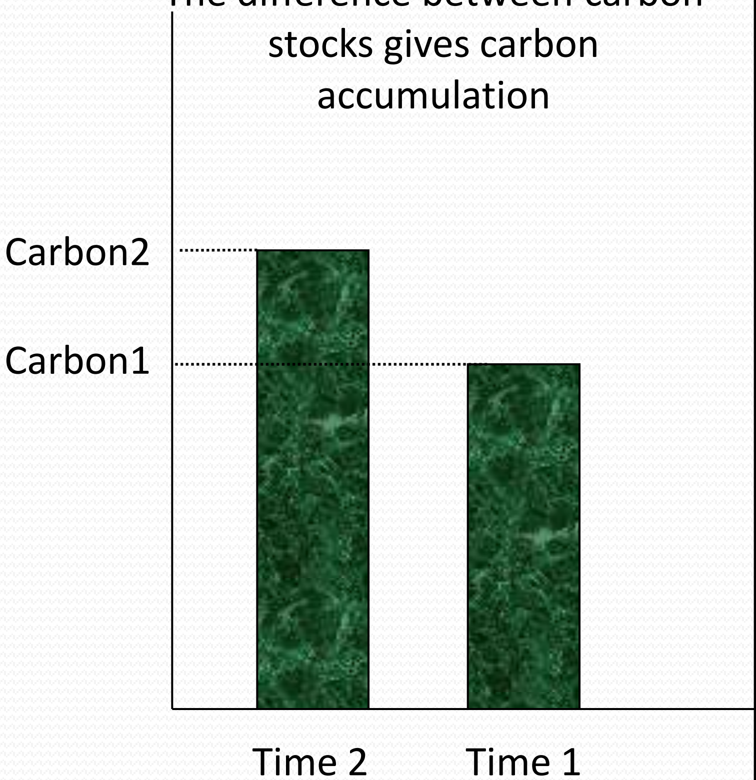


(IPCC, 2003)

Approaches for estimating carbon stock changes

Stock Difference Method

The difference between carbon stocks gives carbon accumulation



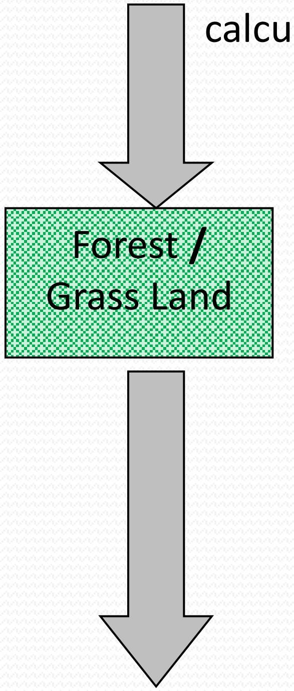
$\Delta C = (C_{t2} - C_{t1}) / (t_2 - t_1)$

Where, ΔC = Changed in C stock

C_{t2} & C_{t1} = Carbon stocks at time t_1 and t_2

Gain-Loss Method

Carbon accumulation is calculated from gain minus loss



Carbon uptake

-Growth
-Enrichment

Carbon release

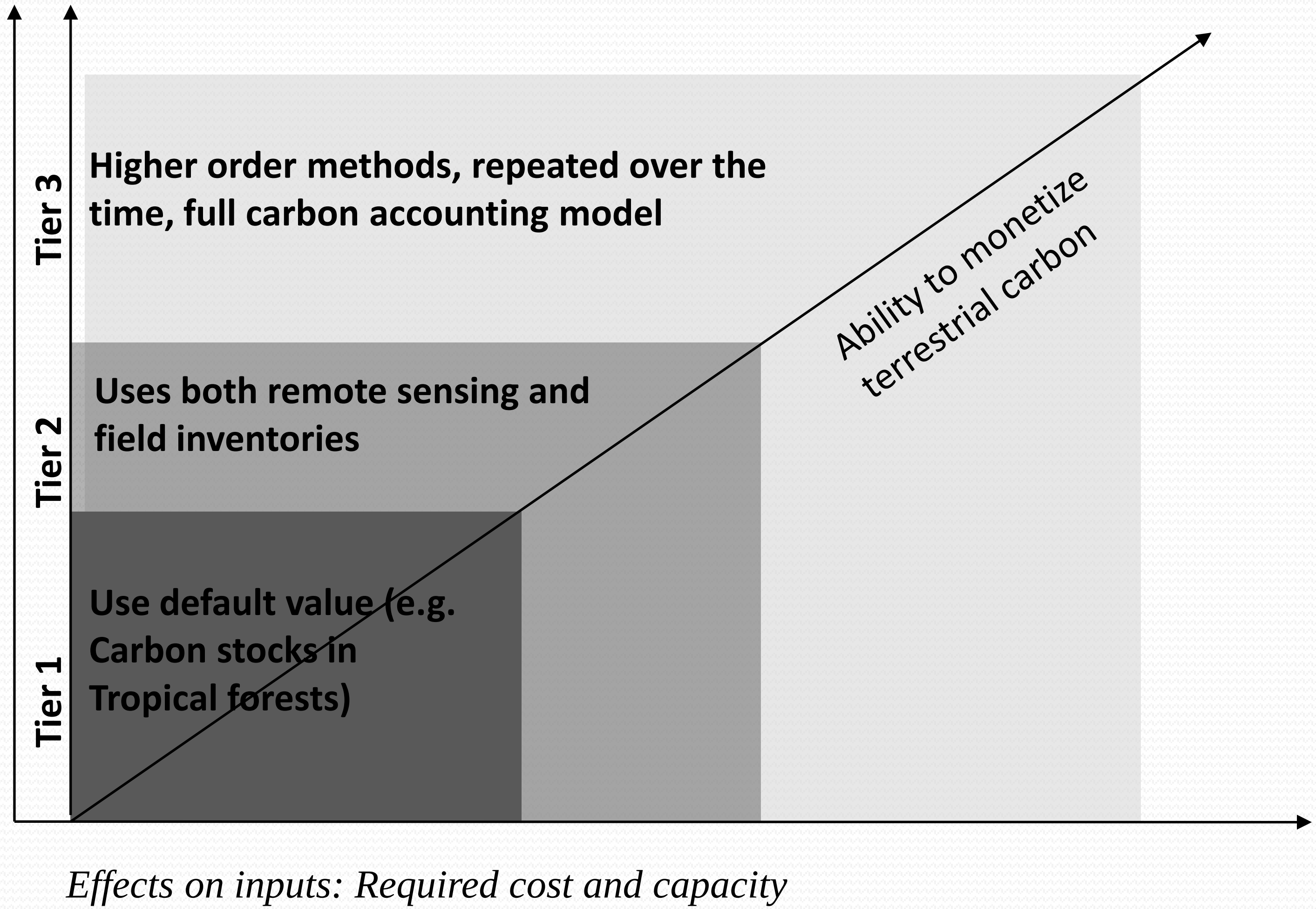
-Timber harvest
-Fuel wood removals
-Charcoal production
-Sub-canopy fires
-Grazing

$\Delta C = \Delta C_G - \Delta C_L$

Where, ΔC = Changed in carbon stock

C_G & ΔC_L = Annual gain & loss of carbon

IPCC Tiers



Overview of the effects of achieving higher quality estimates, adapted from Havemann (2009)

Methodological options for estimating forest carbon and suitability

Pools	Methods	Suitability for carbon measurement
Above-ground biomass	Plot method	Very suitable and cost-effective, commonly adopted and familiar
	Harvest method	Expensive, time consuming , not appropriate all the times
	Plot-less, transect method	Good but not suitable in dense vegetation and for periodic monitoring
	Modelling	Suitable for projections Requires basic input parameters
	Carbon flux measurements	Expensive and needs skilled human resources
	Remote sensing	Expensive for small projects and not suitable for multiple land use systems

Methodological options contd.....

Pools	Methods	Suitability for carbon measurement
Below-ground biomass	Root extraction and weight measurement	Expensive and not suitable
	Root to shoot ratio or conservation factor	Most commonly used Requires AGB measurement
	Biomass equations	Requires input data e.g. height, diameter, girth
Litter and Dead organic matter	Litter trap	Not always suitable and requires huge efforts
	Stock measurement	Feasible and commonly adopted
Soil carbon	Diffuse reflectance spectroscopy	Expensive and requires skill manpower, may be future potential
	Modelling	Suitable for projection, requires input data from other methods
	Laboratory estimation	Most suitable and commonly adopted

Review of forest carbon assessment methods

Methods	Description	Benefits	Limitations	Uncertainty
Biome averages	Estimates of average forest carbon stocks for broad forest categories based on a variety of input data sources	•Immediately available •Free of cost • Globally consistent	• Data sources not properly sampled to large areas • Fairly generalized	High
Forest Inventory	Relates ground-based measurements • diameters or volume • using allometric Eq.	•Low -Tech • Cost depends on the labour availability and cost	•Requires region specific •Can be slow	Low

Source: Gibbs et al., 2007

Review of forest carbon assessment methods

Methods	Description	Benefits	Limitations	Uncertainty
Remote Sensing	Arial extent, volume and change over time if measured more than once.	May be cost- effective, supports field work performance, transparent methodologies, globally consistent, accurate for area estimation	•Some forms of sensor may not be suitable for tropical forests, • Can be technically demanding, can be expensive to interpret results • Not all forms of remote sensing is available for all regions • Not suitable for estimating stocks. • Can not assess the underlying causes of DD	High, medium and low as well

Source: Gibbs et al., 2007

Decision matrix for carbon pools selection

Activity	Carbon pools						
	Living biomass			Dead Biomass		Soil	Wood products
	Above-ground tree	Above-ground non-tree	Below ground	Litter	Dead wood		
REDD Plus	Y	M	R	M	Y	M	M
REDD	Y	M	R	M	M	M	Y
Plantation	Y	N	R	M	M	R	Y
Afforestation	Y	M	Y	M	M	Y	M
Agro-forestry	Y	M	Y	N	N	Y	M
Note: It depends on the standard guidelines, rules and regulations, nature of projects and costs							

Where, Y = Yes: should be measured; M = May be needed; R = Recommended, N = No: Not necessary to measure

(Source: Brown et al., 2000)

Conclusions

- For the successful REDD Plus mechanism a reliable, accurate and cost-effective MRV system is required that can be satisfied by the combine use of RS technologies with ground measurement
- The problem is also that the satellite imagery is very expensive and accessible only to experts who are in short supply
- Clear and practical methodologies are needed not only in field measurement, but also in the application of remote sensing for MRV
- The recent development of technology and methodologies in RS (e.g. LiDar technique data acquisition, radar data) could contribute further to improve precision and accuracy of assessment, if their costs could be brought down.


Thank you
for your attention!!!