Compiling the ecosystem services account: some details on the compilation of various entries

To be used in conjunction with the excel sheet on the exercise

Exercise 3 of the worksheet is the first one on services and we start with carbon sequestration. This illustrates a common approach of using look up tables to estimate certain ecosystem services.

The table to be completed is replicated below for ease of reference; we will go through all the steps suggested in the exercise to complete the table.

Simplified Carbon Stock Account

	Urban and industrial	Annual croplands	Tropical heath forest	Large lowland rivers	Coastal river delta	Total
Opening extent (ha)	**20**	**153**	**90**	**19**	**6**	**288**
Closing extent (ha)	**23**	**145**	**96**	**19**	**5**	**288**
Opening	**100**					
Addition - carbon uptake by biomass	20					
Addition - conversion	15					
Reduction - forest fire	0					
Reduction - conversion	0					
Net Ecosystem Carbon Balance (NECB)	*35*					
Closing	**135**					

Step 1 – Use the look-up table and the extent account to assess opening stocks of carbon

We multiply the opening extent by the carbon storage in the lookup table for the relevant ecosystem type to compute the opening stock of carbon.

Look up table	Carbon storage (tC/ha)	Carbon uptake by biomass (tC/ha)
Artificial surfaces	5	1
Crops	40	4
Grassland	10	2
Tree covered area	200	15
Mangroves	800	100
Shrub covered area	80	5
Regularly flooded areas	300	24
Sparse natural vegetate	8	1
Terrestrial barren land	0	0
Permanent snow, glacie	0	0

For annual cropland, the opening stock of carbon is:

$$153\ ha \times 40\ tC/ha = 6{,}120\ tC\ (tonnes\ of\ carbon)$$

We take a similar approach for all other ecosystem types; results are shown in the table below. Note that we are not considering in this example carbon stored in water; hence the stock of carbon for the river is zero.

Simplified Carbon Stock Account

	Urban and industrial	Annual croplands	Tropical heath forest	Large lowland rivers	Coastal river delta	Total
Opening extent (ha)	20	153	90	19	6	288
Closing extent (ha)	23	145	96	19	5	288
Opening	100	6,120	18,000	0	1,800	26,020

Step 2 – Use the look-up table and the extent change matrix to assess carbon uptake by biomass (i.e., assume that carbon uptake is only taking place in cells that are not converted from one ET (Ecosystem Type) to another)

The ecosystem extent change matric is shown below for ease of reference. The entries in the diagonal of the matrix show the number of hectares for each ecosystem type that were of the same ecosystem type at the opening and closing of the accounting period (i.e., there was no conversion; for example, 20 hectares were urban and industrial at the opening and closing of the accounting period). As noted in the direction for step 2, we assume that carbon update occurs only for those areas that are not converted. Carbon uptake coefficients are shown in the second column of the look-up table above.

Ecosystem Extent Change Matrix (hectares)

		Closing Extent						
		Urban and industrial	Annual croplands	Tropical heath forest	Large lowland rivers	Coastal river delta	Other	**Opening**
Opening Extent	Code							
Urban and industrial		20	0	0	0	0	0	**20**
Annual croplands		3	142	8	0	0	0	**153**
Tropical heath forest		0	2	88	0	0	0	**90**
Large lowland rivers		0	0	0	19	0	0	**19**
Coastal river delta		0	1	0	0	5	0	**6**
Other		0	0	0	0	0	0	**0**
Closing		**23**	**145**	**96**	**19**	**5**	**0**	**288**

For annual croplands, the addition - carbon uptake by biomass is:

$$142\ ha \times 4\ tC/ha = 568\ tC\ (tonnes\ of\ carbon)$$

For tropical heath forest, the addition - carbon uptake by biomass is:

$$88\ ha \times 15\ tC/ha = 1320\ tC\ (tonnes\ of\ carbon)$$

For costal river delta, the addition - carbon uptake by biomass is:

$$5\ ha \times 24\ tC/ha = 120\ tC\ (tonnes\ of\ carbon)$$

Updated table is as follows:

Simplified Carbon Stock Account

	Urban and industrial	Annual croplands	Tropical heath forest	Large lowland rivers	Coastal river delta	Total
Opening extent (ha)	**20**	**153**	**90**	**19**	**6**	**288**
Closing extent (ha)	**23**	**145**	**96**	**19**	**5**	**288**
Opening	**100**	**6,120**	**18,000**	**0**	**1,800**	**26,020**
Addition - carbon uptake by biomass	20	568	1,320	0	120	**2,028**

Step 3 – For all converted areas assume that the conversion takes place completely during the accounting period (e.g., the change in carbon stocks from forest to crops is 200-40 = 160).

In this step we add any additions to the carbon stock due to conversions. We again use the information in the ecosystem extent change matrix and the information in the look up table.

During the accounting period, we have 3 hectares converted into urban and industrial ecosystems. We can find this information by looking at the column for urban and industrial ecosystems in the extent change matrix; 3 hectares that annual croplands at the opening of the accounting period are urban and industrial at the closing of the accounting period.

For annual croplands, the addition - conversion are:

$$3\ ha \times 40\ tC/ha = 120\ tC\ (tonnes\ of\ carbon)$$

For tropical heath forest, the addition - conversion are:

$$8\ ha \times 200\ tC/ha = 1600\ tC\ (tonnes\ of\ carbon)$$

For costal river delta, we have no conversions.

Simplified Carbon Stock Account

	Urban and industrial	Annual croplands	Tropical heath forest	Large lowland rivers	Coastal river delta	Total
Opening extent (ha)	**20**	**153**	**90**	**19**	**6**	**288**
Closing extent (ha)	**23**	**145**	**96**	**19**	**5**	**288**
Opening	**100**	**6,120**	**18,000**	**0**	**1,800**	**26,020**
Addition - carbon uptake by biomass	20	568	1,320	0	120	**2,028**
Addition - conversion	15	120	1,600	0	0	**1,735**

Step 4 – Assume a forest fire takes place in EA02 that reduced the stocks from 215 to 25 for 4 BSUs.

This information is only relevant for the tropical heath forest column of our table. We do not have a change in ecosystem type. Our ecosystem's condition has deteriorated due to the fire, and the stock of CO2 is reduced in the 4 hectares. For each hectare we have a reduction of 190 tonnes of CO2 (215-25 per our assumption). In total then we have a reduction of 760 (190 tonnes of carbon per hectare x 4 hectares).

Before moving to step 5 we also need to calculate the reductions due to conversions. This is similar to step 3, except in this case we are considering reducing in a particular ecosystem type. The information on reductions in ecosystem types can be found by looking at the rows of the extent change matrix. When looking at the first row on urban and industrial ecosystems we see that there are no reductions; there were zero hectares that changed from urban and industrial to some other ecosystem type.

For annual croplands, we have a reduction of 11 hectares (3 hectares became urban and industrial and 8 became tropical heath forest—an unlikely change in practice but we have it here in this made-up example!)

For annual croplands, reductions- conversion are:

$$11\ ha \times 40\ tC/ha = 440\ tC\ (tonnes\ of\ carbon)$$

For tropical heath forest, reductions - conversion are:

$$2\ ha \times 200\ tC/ha = 400\ tC\ (tonnes\ of\ carbon)$$

For costal river delta, reductions - conversion are:

$$1\ ha \times 300\ tC/ha = 300\ tC\ (tonnes\ of\ carbon)$$

Simplified Carbon Stock Account

	Urban and industrial	Annual croplands	Tropical heath forest	Large lowland rivers	Coastal river delta	Total
Opening extent (ha)	**20**	**153**	**90**	**19**	**6**	**288**
Closing extent (ha)	**23**	**145**	**96**	**19**	**5**	**288**
Opening	**100**	**6,120**	**18,000**	**0**	**1,800**	**26,020**
Addition - carbon uptake by biomass	20	568	1,320	0	120	**2,028**
Addition - conversion	15	120	1,600	0	0	**1,735**
Reduction - forest fire	0	0	760	0	0	**760**
Reduction - conversion	0	440	400	0	300	**1,140**

Step 5 – Calculate the net changes. These net changes are called NECB (net ecosystem carbon balance – which is the metric proposed (aligned with IPCC guidelines) to estimate carbon sequestration.

Step 6 – Calculate the closing stocks.

We will do the last 2 steps together. To calculate NECB we need to add the addition rows (carbon uptake and conversion) and subtract the reductions (forest fire and conversion). For urban and industrial ecosystems NECB is 35 (20+15-0-0). And the closing stock is opening stock plus/minus NECB. For urban and industrial it would be 135 (opening of 100 plus 35 from NECB).

For annual croplands NECB is 248 (568+120-0-440). And closing stock is 6368 (opening of 6120 and NECB of 248).

The final table follows below.

Simplified Carbon Stock Account

	Urban and industrial	Annual croplands	Tropical heath forest	Large lowland rivers	Coastal river delta	Total
Opening extent (ha)	**20**	**153**	**90**	**19**	**6**	**288**
Closing extent (ha)	**23**	**145**	**96**	**19**	**5**	**288**
Opening	**100**	**6,120**	**18,000**	**0**	**1,800**	**26,020**
Addition - carbon uptake by biomass	20	568	1,320	0	120	**2,028**
Addition - conversion	15	120	1,600	0	0	**1,735**
Reduction - forest fire	0	0	760	0	0	**760**
Reduction - conversion	0	440	400	0	300	**1,140**
Net Ecosystem Carbon Balance (NECB)	*35*	*248*	*1,760*	*0*	*-180*	***1,863***
Closing	**135**	**6,368**	**19,760**	**0**	**1,620**	**27,883**

Exercise 4 of the worksheet asks us to compute the provisioning of crop services. This illustrates a common approach of modeling to estimate ecosystem services.

Crop provision services are only relevant to ecosystems of the type “Annual croplands”.

Instructions and steps for the exercise are as follows:

Assume that the total crop yield in EA01 was 18,700 tons/year.

Step 1: Calculate average rainfall for EA01 taking into consideration that EA01 spreads across 2 rainfall zones.

From the extent calculations, we know that EA01 is 80 hectares. As shown in the map, 10 hectares receive 170mm of rainfall a year and 70 hectares receive 190mm of rainfall per year. Average rainfall per hectare is:

$$\frac{(10\ ha \times 170\ mm/ha) + (70\ ha \times 190\ mm/ha)}{80\ ha} = 172.5\ mm/ha$$

Step 2: Calculate yield per ha for EA01

We are given that the total crop yield for EA01 was 18,700 tons/year. The yield per hectare is:

$$\frac{18{,}700\ tons/year}{80\ ha} = 233.75\ \ tons/year/ha$$

Step 3: Calculate yield per ha for EA04 based on the biophysical model

The biophysical model we have is a simplified one—there is a linear relationship between rainfall and crop yield. To calculate the yield per hectare for EA04, we have:

$$\frac{150\ mm/ha\ (EA04)}{172.5\ mm/ha(EA01)} \times 233.75\ tons/ha(EA01) = 203.26\ tons/ha(EA04)$$

Note that EA04 is receiving 150 mm of rainfall per hectare. For ease of presentation, we have removed time unit (year) since it is the same for all numbers; in all cases is for 1 year.

Step 4: Aggregate across whole extent of EA04.

EA04 is 45 hectares. We can now compute the total crop yield for EA04 as follows:

$$203.26\ tons/ha \times 45\ ha = 9{,}147\ tons$$

Exercise 5: Estimate unknown ecosystem services and supply account

We are now given a partially completed supply account and need to complete some of the empty cells based on the computations in exercises 3 and 4. The given table is replicated below.

Services Supply Table

EU	Extent (ha)	(C) Crop tonnes/year	(R) Recreation trips/year	(W) Water m^3/year	(S) Carbon Sequestration tonnes /year
EA01 = Annual croplands		18,700	500		
EA02 = Tropical heath forest			1,500		270
EA03 = Large lowland rivers			1,600	15,000	
EA04 = Annual croplands					
EA05 = Tropical heath forest					
EA06 = Urban and industrial			500	0	
EA07 = Urban and industrial			700	0	
EA08 = Coastal river delta		700	5,000	0	
EA09 = Large lowland rivers					
EA10 = Tropical heath forest					
EA11 = Annual croplands		6,545			
Total	-				

Step 1: use information from the carbon account to fill out the information on carbon sequestration.

Here are some things to keep in mind for step 1.

- The carbon sequestration component of the service reflects the ability of ecosystems to remove carbon from the atmosphere.
- It is assumed that carbon sequestration concerns only carbon that is expected to be stored for long periods of time. This may involve storage within an ecosystem asset, e.g., a mangrove or wetland, or another form of storage (e.g., in the economy).
- Carbon that is sequestered but not expected to be stored, e.g., crops, should be excluded from scope.
- An appropriate metric is the net ecosystem carbon balance. Where net carbon sequestration is zero or negative, the level of service supplied by an ecosystem will be zero.

For ease of reference here is the relevant part of the table from exercise 3.

Simplified Carbon Stock Account

	Urban and industrial	Annual croplands	Tropical heath forest	Large lowland rivers	Coastal river delta	Total
Net Ecosystem Carbon Balance (NECB)	*35*	*248*	*1,760*	*0*	*-180*	***1,863***

The NECB for urban and industrial ecosystems does not reflect the ability of the ecosystem to remove carbon from the environment; it is due to the increase in ecosystem extent. Hence, the 35 tonnes of carbon would not be considered a service.

For annual croplands, while we have carbon sequestration, it is expected to be stored long term since the crops are to be harvested and consumed. Again, this would not be included as a service.

For costal river deltas, we have a negative NECB and there is no service being provided. Note that we are not considering in this exercise carbon stored in water (also known as blue carbon).

The only ecosystem type that is providing carbon sequestration service is the tropical heath forest; the service provided is in the amount 1,760 tonnes of carbon sequestered (270 in EA01, 1,380 in EA05 and 110 in EA10). The update ecosystem supply table is as follows:

Services Supply Table

EU	Extent (ha)	(S) Carbon Sequestration tonnes /year
EA01 = Annual croplands	80	0
EA02 = Tropical heath forest	42	270
EA03 = Large lowland rivers	11	0
EA04 = Annual croplands	45	0
EA05 = Tropical heath forest	12	1,380
EA06 = Urban and industrial	9	0
EA07 = Urban and industrial	11	0
EA08 = Coastal river delta	6	0
EA09 = Large lowland rivers	8	0
EA10 = Tropical heath forest	36	110
EA11 = Annual croplands	28	0
Total	**288**	**1,760**

Step 2: fill out the information on crop supply for EA04 (orange cell) from exercise 4 above and **Step 3:** estimate the remaining values from nearest neighbor for (C), (R) and (W) for the missing EAs; e.g., Crop for EA11 = Crop for EA01 / 80 * 28.

We will do steps 2 and 3 together. We are using another common approach to estimating ecosystem services by considering flows from the nearest neighbor.

EA11 is annual cropland and the closest ecosystem asset (nearest neighbor) of the same type is EA01. To estimate the crop provision services from EA11 we use the information we have for EA01. We earlier calculated the crop yield for EA01—233.75 tons/ha. EA11 is 28 hectares and we have an estimated crop yield for all of EA11:

$$233.75\ tons/ha \times 28\ ha = 6{,}545\ tons$$

For recreation, we take a similar approach to estimating the number of trips/year in each ecosystem type.

EA04 is annual cropland and the nearest neighbor for which we have data on recreational services is EA01. We can estimate the number of trips in EA04 as follows:

$$\frac{500\ trips/year\ (EA01)}{80\ ha\ (EA01)} \times 45\ ha(EA04) = 281\ trip/year(EA04)$$

EA11 is also annual cropland, and we use the same information.

$$\frac{500\ trips/year\ (EA01)}{80\ ha\ (EA01)} \times 28\ ha(EA11) = 175\ trip/year(EA11)$$

For the other ecosystem types we follow a similar approach to calculate the trips in each ecosystem asset.

The last service we need to estimate is water provisioning services which is being provided by the large lowland rivers ecosystem assets (EA03 and EA09). EA03 provides 15,000 cubic meters of water. And we can use this to estimate water provided by EA09 as follows:

$$\frac{15{,}000\ m^3/year\ (EA03)}{11\ ha\ (EA03)} \times 8\ ha(EA09) = 10{,}909\ m^3/year(EA09)$$

Services Supply Table

EU	Extent (ha)	(C) Crop tonnes/year	(R) Recreation trips/year	(W) Water m^3/year	(S) Carbon Sequestration tonnes /year
EA01 = Annual croplands	80	18,700	500	0	0
EA02 = Tropical heath forest	42	0	1,500	0	270
EA03 = Large lowland rivers	11	0	1,600	15,000	0
EA04 = Annual croplands	45	9,147	281	0	0
EA05 = Tropical heath forest	12	0	429	0	1,380
EA06 = Urban and industrial	9	0	500	0	0
EA07 = Urban and industrial	11	0	700	0	0
EA08 = Coastal river delta	6	700	5,000	0	0
EA09 = Large lowland rivers	8	0	1,164	10,909	0
EA10 = Tropical heath forest	36	0	1,286	0	110
EA11 = Annual croplands	28	6,545	175	0	0
Total	**288**	**35,092**	**13,134**	**25,909**	**1,760**

Step 4: Calculate totals for each service and **Step 5**: Aggregate the results by ET in the table below.

Services Supply Account

EU Type	Extent (ha)	(C) Crop Tonnes	(R) Recreation Trips	(W) Water m^3	(S) Carbon Sequestration tonnes
Urban and industrial	20	-	1,200	-	-
Annual croplands	153	**34,392**	956	-	-
Tropical heath forest	90	-	**3,214**	-	1,760
Large lowland rivers	19	-	2,764	**25,909**	-
Coastal river delta	6	700	5,000	-	-
Total	**288**	**35,092**	**13,134**	**25,909**	**1,760**

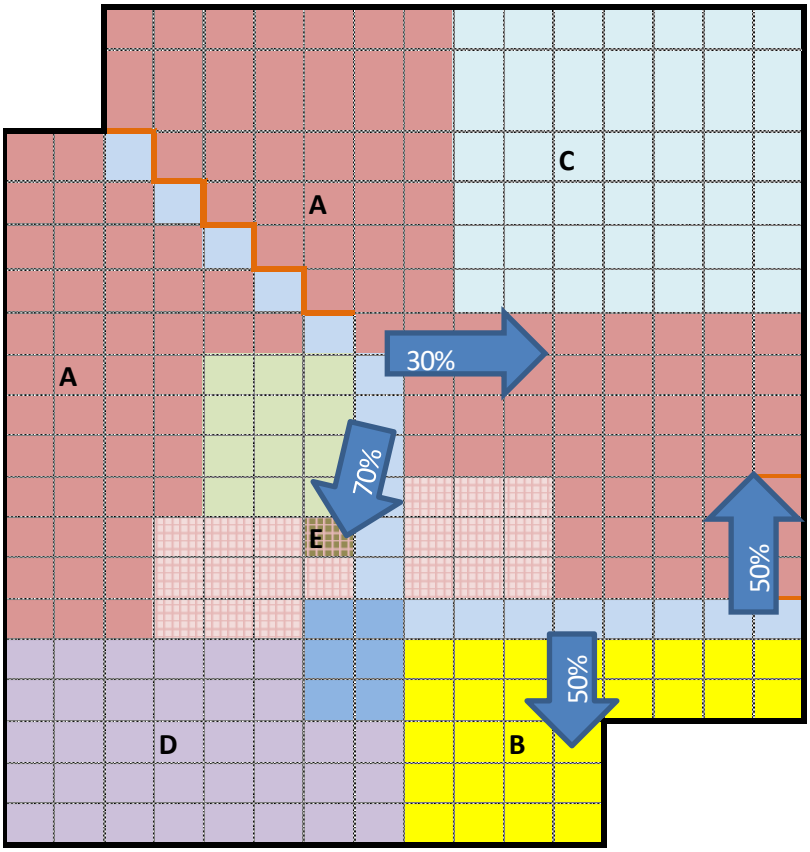
Exercise 6: Compile ecosystem service use account

Having compiled the supply account, we now turn our attention to the use table. Recall that for each ecosystem service that we record, there is an ecosystem supplying it and there is a user of that service.

Instructions

- Assume that all visits to the forest EA10 (i.e., D) are for a campsite
- Assume that the crop production from the costal river delta is undertaken by households
- Water use allocation percentages are indicated in the figure below.
- Check your answer as supply needs to equal use (for each individual ecosystem service)!

Beneficiaries



Eco ISIC - Classification of economic activities

A	0111 - Growing of cereals (except rice), leguminous crops and oil seeds
B	Other agriculture
C	0113 - Growing of vegetables and melons, roots and tubers
D	5520 - Camping grounds, recreational vehicle parks and trailer parks
E	36 - Water collection, treatment and supply
F	Households
G	Government

Crop provisioning

We will consider each of the services in turn staring with crop provisioning services. Looking at the map above and the map on ecosystem extent, the beneficiary of the crop provisions from EA01 and EA04 is the agricultural industry, 0111-Growing of cereals. The amount of crops is 27,847 tones (18,700 from EA01 and 9,147 tones from EA04).

EA11 supplied 6,545 tones of crops and the beneficiary is the agricultural-other

Finally we have 700 tones of crops from EA08 which are to be allocated to households as noted in the assumptions.

The updated use table is as follows below. Note that the total use is the same as the total supply.

Services Use Account

		(C) Crop
Beneficiaries (based on survey		Tonnes
Agriculture - cereals		27,847
Agriculture - other		6,545
Water supply sector		
Recreation		
Households		700
Government		
Total		**35,092**

Recreation

In total there were 13,134 trips taken to the various ecosystem assets. In the assumption, we are informed that beneficiary industry of the trips to EA10 is the camping industry (there is a campsite in the forest that is being used and users are using the campsite for the trip). We can further assume that the rest of the trips are being undertaken by households.

There were 1,286 trips taken to EA10. The use table would be as follows:

Services Use Account

		(C) Crop	(R) Recreation
Beneficiaries (based on survey		Tonnes	Trips
Agriculture - cereals		27,847	
Agriculture - other		6,545	
Water supply sector			
Recreation			1,286
Households		700	11,848
Government			
Total		**35,092**	**13,134**

Water provisioning

Total supply of water from the 2 ecosystem assets that are large lowland rivers (EA03 and EA09) is 25,909 cubic meters of water. EA03 is supplying 15,000 cubic meters and EA09 is supplying 10,909 cubic meters. From the map of beneficiaries above we know the following: 70% of the water from EA03 is being used by the water collection industry and 30% is being used by the Agricultural-cereals industry; and 50% of the water from EA09 is being used by the Agricultural-cereals industry and 50% is being used by the Agricultural-other industry. Using this information we have the following:

Water use by the water supply sector: $15{,}000\ cubic\ meters \times 70\% = 10{,}500\ cubic\ meters$

Water use by agriculture-cereals: $15{,}000 \times 30\% + 10{,}909 \times 50\% = 9{,}945.5\ cubic\ meters$

Water use by agriculture-other: $10{,}909\ cubic\ meters \times 50\% = 5{,}454.5\ cubic\ meters$

Services Use Account

		(C) Crop	(R) Recreation	(W) Water
Beneficiaries (based on survey)		Tonnes	Trips	m^3
Agriculture - cereals		27,847		9,955
Agriculture - other		6,545		5,455
Water supply sector				10,500
Recreation			1,286	
Households		700	11,848	
Government				
Total		**35,092**	**13,134**	**25,909**

Carbon sequestration

The final service we have is carbon sequestration. The beneficiaries of this services are all of us and by convention it is included in government.

Services Use Account

		(C) Crop	(R) Recreation	(W) Water	(S) Carbon Sequestration
Beneficiaries (based on survey)		Tonnes	Trips	m^3	tonnes
Agriculture - cereals		27,847		9,955	
Agriculture - other		6,545		5,455	
Water supply sector				10,500	
Recreation			1,286		
Households		700	11,848		
Government					1,760
Total		**35,092**	**13,134**	**25,909**	**1,760**

We now have a full accounting of the supply and use of the various ecosystem services. We know which ecosystem provided the services and who are the users of those services.