Literature review and database on ecosystem service valuation studies for Kenya and Vietnam

This review aimed to compile a database of values for ecosystem services in Kenya and Vietnam. The search period for literature was from July 15 to September 15, 2022. The Scopus database and the Ecosystem Services Valuation database were used to identify relevant papers. A total of 162 papers are in the database, with 76 papers about Kenya and 86 about Vietnam. There are 1573 values in the database, 784 for Kenya and 789 for Vietnam. The data collected from each paper in the database included the type of biome, ecosystem service, raw data for the ecosystem service value and the method of ecosystem service value estimation. The variables for which data was collected were based on The Economics of Ecosystems and Biodiversity (TEEB) framework. The TEEB framework allows for the categorization of biomes, sub biomes and types of ecosystem services to be standardized. The ecosystem services are divided into three levels of classification: ecosystem services, ecosystem sub-services and ecosystem sub-sub-services.

Data collection

To identify papers published in peer-reviewed academic journals, topic keywords were chosen. Initially three key words were chosen to serve as categories from which the key word list could be expanded. These were, 'ecosystem,' 'valuation,' and 'area.' The key words in the category of 'ecosystem' included all the biomes in the TEEB database and synonyms for the word 'environment'. The words listed under the 'valuation' category were selected using the types of methodologies listed in the TEEB framework. 'Area' included Vietnam and Kenya. The papers that were included were published between the years 2005-2022. The search string for both countries is provided in Annex 1.

The key words were used to search for relevant papers in the Scopus database. Another filter was used to remove papers about medicine, biochemistry, genetics and molecular biology and immunology and molecular biology in the Scopus database. Papers were not identified through a keyword search in The Ecosystem Services Valuation Database but were filtered by country and by year of publication. The review did not include marine environments, however saltwater wetlands and mangroves were included. Annex 2 provides the flow diagrams for the search and screening process for Kenya and Vietnam.

As each paper had to be assigned to a biome and sub-biome as per the TEEB database, there may be errors in terms of the classification of each biome as decisions on the type of biome was made by the researcher and classification for this variable is somewhat subjective.

Calculation of results

For comparability, all the values for ecosystem services in the database were converted to USD 2022 per hectare per year. This included 3 steps. 1) Convert the raw data to a per hectare value. 2) Convert the value to USD in the year that the value was obtained. 3) Convert the USD values to USD 2022.

Obtaining per hectare values

Where papers did not provide a per hectare value for the ecosystem services values in the paper, a per hectare value had to be calculated. Calculating the per hectare value often needed the data for the size of the study area, the number of households in the area or the population of the area. If this data was not provided in the paper, external sources were used.

Population and number of households in a province, district, or county were obtained from the Kenya National Bureau of Statistics. The size of areas were also obtained from the Kenya National Bureau of Statistics. Similar data for Vietnam was not as readily available and was obtained from Wikipedia. The

references listed on Wikipedia for the data were from the General Statistics Office of Vietnam. Estimating data that was not provided in the paper could lead to either overestimation or underestimation of the final USD per hectare value.

Where the total number of households or population in a study area could not be calculated, the sample size was used to calculate per hectare value. This led to a vastly underestimated per hectare value, but this option was preferrable to removing the value from the database entirely.

Obtaining USD 2022 per hectare per year values

To standardize the data, all the values in the database were converted to a USD 2022 per hectare per year value. The value was first converted into USD for the year of valuation and then converted to USD 2022. The values given in Vietnamese Dong and in Kenyan Shillings were converted to USD using conversion rates retrieved from the World Bank. To convert values given in Euros, data from the European Central Bank was used. To adjust the USD values for inflation and convert them to USD 2022, the Consumer Price Index (CPI) from the U.S. Bureau of Labor Statistics was used.
The formula for calculating inflation adjusted values is below:

$$USD\ 2022\ value = \frac{CPI\ in\ 2022}{CPI\ in\ year\ value\ was\ calculated} \times USD\ value$$

The average value of each ecosystem service is given in Table 1. The results were calculated by dividing the total value of each ecosystem service across papers by the number of values there were for each ecosystem service. The total value across papers was obtained by summing all the values per hectare that were in the database for each ecosystem service.
These results are based purely on the raw data from papers adjusted to USD 2022 dollars. There was no refinement of the results to remove outliers from the data and the data was not weighted. Net present values (NPV) were divided by the number of years over which the NPV analysis was conducted. USD per hectare values for 25 of the 162 papers could not be calculated due to a lack of data.

Additions to the TEEB framework

Two new ecosystem sub-sub-services were added to the framework. Under the TEEB framework, there is an ecosystem sub-service category for 'Medicine.' Under this ecosystem sub-service there were four ecosystem sub-sub-services. These included 'biochemicals,' 'models,' 'test-organisms,' and 'bioprospecting.' They describe mainly commercial uses of forest resources for medical purposes. There were no papers in the review that reported values for these ecosystem services. To this end, the researcher added a supplementary ecosystem sub-sub-service to include the use of medicinal plants on a local level. This new ecosystem sub-sub-service was named, 'Medicinal plants.'
An additional ecosystem sub-sub-service was added to the 'food' ecosystem sub-service as 'food [other]'. This included income from food that was produced through agricultural systems as opposed to food collected from ecosystems.

Results

Table 1: Average per hectare values for Kenya and Vietnam. In red are ecosystem services, in blue are ecosystem sub-services, in black are ecosystem sub-sub-services. '-' is used for ecosystem services for which there were no values.

Ecosystem services, ecosystem sub-services and ecosystem sub-sub services	Ecosystem Service Values (USD 2022/hectare/year)	
	Average value per hectare- Vietnam	Average value per hectare- Kenya
PROVISIONING SERVICES	12997.198	4514.700
Food	21183.690	1166.143
Fish	36862.456	229.473
Meat	1.714	314.948
Plants / vegetable food	13.274	-
Non-timber forest products [food only]	0.505	1072.296
Food [general]	876.598	1948.884
Food [other]	2173.954	2375.150
Water	80.958	18059.195
Drinking water	-	-
Industrial water	-	-
Water other	59.071	76.390
Irrigation water [unnatural]	-	1053.546
Water supply [general]	91.201	50232.814
Raw materials	260.179	3187.888
Fibers	-	46.117
Timber	319.827	135.516
Fuel wood and charcoal	24.514	169.821
Fodder	-	51.169
Fertilizers	-	103881.693
Other raw	9.249	8.402
Raw materials [general]	324.496	77.990
Sand, rock, gravel, coral etc	-	120.429
Biomass fuels	-	1.839
Genetic	255.601	30.687
Plant genetic resources	0.003	-
Animal genetic resources	-	0.134
Genetic resources [general]	596.398	152.897
Medical	0.123	26.854
Biochemicals	-	-
Models	-	-
Test-organisms	-	-
Bioprospecting	-	-
Medicinal plants	0.123	26.854
Ornamental	-	-
Decorative plants	-	-
Fashion	-	-
Decorations / Handicrafts	-	-
Pets and captive animals	-	-

Ecosystem services, ecosystem sub-services and ecosystem sub-sub services	Ecosystem Service Values (USD 2022/hectare/year)	
	Average value per hectare- Vietnam	Average value per hectare- Kenya
REGULATING SERVICES		
Air quality	-	-
Capturing fine dust	-	-
Air quality regulation [general]	-	-
UVb-protection	-	-
Climate	3894.900	9338.058
C-sequestration	5502.621	10241.851
Climate regulation [general]	551.321	679.555
Microclimate regulation	-	-
Gas regulation	3.735	70.754
Extreme events	596.552	406.982
Storm protection	4.601	-
Flood prevention	-	406.982
Fire prevention	-	-
Prevention of extreme events [general]	2085.630	-
Water flows	-	523.954
Drainage	-	523.954
River discharge	-	-
Natural irrigation	-	-
Water regulation [general]	-	-
Waste	537.296	-
Water purification	1693.433	-
Soil detoxification	-	-
Abatement of noise	-	-
Waste treatment [general]	151.917	-
Erosion	3933.124	477.175
Erosion prevention	3933.124	477.175
Soil fertility	402.250	323.539
Maintenance of soil structure	-	24.229
Deposition of nutrients	-	-
Soil formation	50.307	40.294
Nutrient cycling	812.850	679.271
Maintenance of soil fertility [general]	-	550.360
Pollination	3.566	1892.124
Pollination of crops	-	1983.923
Pollination of wild plants	-	-
Pollination [general]	3.566	193.845
Biological control	12.350	176.794
Seed dispersal	-	-
Pest control	-	177.579
Disease control	-	-
Biological Control [general]	12.350	176.402

Ecosystem services, ecosystem sub-services and ecosystem sub-sub services	Ecosystem Service Values (USD 2022/hectare/year)	
	Average value per hectare- Vietnam	Average value per hectare- Kenya
HABITAT	128.592	136.532
Life cycles	532.768	107.414
Nursery service	-	107.414
Refugia for migratory and resident species	532.768	-
Genetic Diversity	110.220	143.811
Biodiversity protection	110.220	143.811
CULTURAL	677.237	191.798
Aesthetic	-	-
Attractive landscapes	-	-
Recreation	869.821	102.057
Recreation	270.636	232.967
Tourism	1319.209	100.092
Ecotourism	-	15.009
Hunting and fishing	-	1.268
Inspiration	3.195	10.636
Artistic inspiration	-	-
Cultural use	3.195	10.636
Inspiration [general]	-	-
Spiritual	-	-
Spiritual / Religious use	-	-
Cognitive	-	982.189
Science / Research	-	82.710
Education	-	2331.407
Cognitive [general]	-	-
ADDITIONAL AND GENERAL	1045.991	57471.691
Various	1159.123	58412.497
Various	1159.123	58412.497
Other	16.654	65097.775
Other ecosystem sub-services	16.654	65097.775
Total economic value	-	3285.573
Total economic value	-	3285.573
Energy	-	2.675
Hydro-electricity	-	2.817
Solar energy	-	2.108
Wind energy	-	-
Other energy	-	-
Thermal energy	-	-
Cultural values	71.496	6.783
Cultural values [general]	71.496	6.783
Provisioning values	-	-
Provisioning values [general]	-	-
Regulating values	1485.817	-

Ecosystem services, ecosystem sub-services and ecosystem sub-sub services	Ecosystem Service Values (USD 2022/hectare/year)	
	Average value per hectare- Vietnam	Average value per hectare- Kenya
Regulating [general]	1485.817	-
Habitat	-	60.566
Supporting [general]	-	60.566

The results of the USD per hectare analysis are given in Table 1. The next section provides a short description of each ecosystem service for Kenya and Vietnam.

Kenya

Provisioning

Provisioning ecosystem services included mainly the value of food such as fish and non-timber forest products and the value of raw materials such as timber and other raw products. Most of the papers that were classified under the ecosystem sub-service timber estimated the net present value of timber plantations and the value of poles extracted from the forest. The ecosystem sub-service Other raw includes items such as thatching grass and insect-based feed for poultry and livestock.

Regulating

Climate and pollination ecosystem sub-services had the largest regulating values for Kenya, 9338.058 USD/hectare/year and 1892.124 USD/hectare/year respectively. Multiple papers estimated the value of carbon sequestration of mangroves and of forest areas. There were 39 values estimating the value of pollination, however there were only 2 papers that estimated the value of pollination, so this value may not be reliable.

Habitat

Habitat ecosystem services had the lowest ecosystem service value. There were only 10 values classified under this service. Most of the values categorized under habitat were for the value of biodiversity protection.

Cultural

There were only 47 values in the database for this ecosystem service. All values were listed under either the recreational or inspiration ecosystem sub-sub-service. Recreation was mainly income generated from tourism activities in tropical forests, grasslands and mangrove areas. There were only 2 values estimated for inspiration sub-service. These were the values for the ritual sites for male circumcision in the Kakamega forest and the willingness to pay for cultural services in the Elgeyo watershed.

Additional and general

Additional and general ecosystem services had the largest value. This is because out of 784 recorded values for Kenya, 117 values were categorized under the ecosystem sub-sub-service various and 155 were categorized under other. Many papers looked at the net benefit of different types of crops or methods of farming. Other papers estimated the value of different forest products to local communities. These were all classified under various. Papers that were classified under other dealt mainly with estimating the values of livestock.

Vietnam

Provisioning

Provisioning ecosystem services are worth the most in Vietnam. At 12,997.198 USD/hectare/year, it is three times the value of the other four ecosystem services combined. The most valuable ecosystem sub-services under the provisioning ecosystem service are for food, 21,183.690 USD/hectare/year, and raw materials, 260.179 USD/hectare/year. The largest values under food are for fish and food [other]. The values under these ecosystem services were mainly from estimates of profitability for shrimp farms and from aquaculture. It also includes values for subsistence fisheries in mangroves and rivers.

Regulating

The climate and erosion ecosystem sub-services had the highest values under this ecosystem service, at 3,894.900 USD/hectare/year and 3,933.124 USD/hectare/year respectively. Most of the papers that reported values for climate looked at the value of carbon sequestration in forests. Under the ecosystem sub-service erosion, papers estimated the value of erosion control in a mangrove and a nature reserve.

Habitat

Habitat has a value of 128.597 USD/hectare/year, the lowest of all the ecosystem service categories. Most of the values categorized under habitat were for the value of biodiversity protection.

Cultural

The cultural values obtained mainly from papers that estimated values from tourism and recreation.

Additional and general

The values categorized under this ecosystem service had the second highest number of values for Vietnam in the database after those categorized under provisioning services. The ecosystem sub-sub-services regulating [general] and various were worth the most per hectare, an estimated 1,485.817 USD/hectare/year and 1,159.123 USD/hectare/year respectively. However, there was only one value in the database under Regulating [general], so the value of USD 1485.816 USD/hectare/year for this ecosystem sub-sub- service is based on this single value. This value was the estimated value of regulating services in the Thai Thuy wetland. Most of the values categorized under various were for PES payments.

Next steps

Data manipulation

As is, the data is in a raw state. The USD per hectare values need to be adjusted to remove outliers. The data also needs to be weighted. In addition to this, areas for papers for which areas were not provided or could not be located need to be estimated. Additionally, because the estimated size of areas obtained from government sources may not be the actual size of the study area, more accurate maps could be used to estimate the study area. Once area sizes for each paper are finalized, the total value of each biome within Kenya and Vietnam can be estimated. The values can also be plotted on a map for easier visualization.

Valuing sustainable agricultural methods

Although it was not specifically included in the scope in this review, there were several papers about sustainable agriculture that are included in this database. There is considerable scope for a future study to estimate the value of sustainable agriculture in Kenya and Vietnam.

Implications for policy

This database provides the bones to develop a story for in-depth analysis of land use changes and policies that affect ecosystem services Vietnam and Kenya.

This database can be used in local contexts in a benefit transfer for modelling land use changes in Kenya and Vietnam. The data could be used in a benefit transfer study to estimate land use changes in Kenyan counties under the Nature+ project.

Most of the households benefitting from the ecosystem services in the papers reviewed were households which were employed in the agricultural sector. The results could be used to argue for better management of forest resources extracted by farmers and rural communities.

There were 24 papers that explored PES systems in Vietnam. Many of the papers highlighted that PES payments were less than the actual ecosystem service value. Values obtained for ecosystem services for Vietnam from this database can be employed to make the case for an increase in PES payments.

Annex 1

Search string for Kenya

(TITLE-ABS-KEY ({ecosystem service}) OR TITLE-ABS-KEY ({ecosystem good}) OR TITLE-ABS-KEY (ecosystem) OR TITLE-ABS-KEY (forest) OR TITLE-ABS-KEY (environment) OR TITLE-ABS-KEY (environmental) OR TITLE-ABS-KEY (biodiversity) OR TITLE-ABS-KEY (biome) OR TITLE-ABS-KEY (commons) OR TITLE-ABS-KEY (mangrove) OR TITLE-ABS-KEY (wetland) OR TITLE-ABS-KEY (river) OR TITLE-ABS-KEY (lake) OR TITLE-ABS-KEY (desert) OR TITLE-ABS-KEY (mountain) OR TITLE-ABS-KEY (habitat) OR TITLE-ABS-KEY (crop) OR TITLE-ABS-KEY (perennial) OR TITLE-ABS-KEY (grassland) OR TITLE-ABS-KEY (woodland) OR TITLE-ABS-KEY (scrubland) OR TITLE-ABS-KEY (savanna) OR TITLE-ABS-KEY (conservation) OR TITLE-ABS-KEY ({natural capital}) AND TITLE-ABS-KEY (valuation) OR TITLE-ABS-KEY (value) OR TITLE-ABS-KEY (assessment) OR TITLE-ABS-KEY (monetary) OR TITLE-ABS-KEY (benefit) OR TITLE-ABS-KEY (cost) OR TITLE-ABS-KEY (economic) OR TITLE-ABS-KEY ({economic valuation}) OR TITLE-ABS-KEY ({cost-benefit analyis}) AND TITLE-ABS-KEY (kenya) OR TITLE-ABS-KEY (kenyan)) AND PUBYEAR > 1999 AND (EXCLUDE (SUBJAREA , "medi") OR EXCLUDE (SUBJAREA , "bioc") OR EXCLUDE (SUBJAREA , "engi") OR EXCLUDE (SUBJAREA , "immu"))

Search string for Vietnam

(TITLE-ABS-KEY ({ecosystem service}) OR TITLE-ABS-KEY ({ecosystem good}) OR TITLE-ABS-KEY (ecosystem) OR TITLE-ABS-KEY (forest) OR TITLE-ABS-KEY (environment) OR TITLE-ABS-KEY (environmental) OR TITLE-ABS-KEY (biodiversity) OR TITLE-ABS-KEY (biome) OR TITLE-ABS-KEY (commons) OR TITLE-ABS-KEY (mangrove) OR TITLE-ABS-KEY (wetland) OR TITLE-ABS-KEY (river) OR TITLE-ABS-KEY (lake) OR TITLE-ABS-KEY (desert) OR TITLE-ABS-KEY (mountain) OR TITLE-ABS-KEY (habitat) OR TITLE-ABS-KEY (crop) OR TITLE-ABS-KEY (perennial) OR TITLE-ABS-KEY (grassland) OR TITLE-ABS-KEY (woodland) OR TITLE-ABS-KEY (scrubland) OR TITLE-ABS-KEY (savanna) OR TITLE-ABS-KEY (conservation) OR TITLE-ABS-KEY ({natural capital}) AND TITLE-ABS-KEY (valuation) OR TITLE-ABS-KEY (value) OR TITLE-ABS-KEY (assessment) OR TITLE-ABS-KEY (monetary) OR TITLE-ABS-KEY (benefit) OR TITLE-ABS-KEY (cost) OR TITLE-ABS-KEY (economic) OR TITLE-ABS-KEY ({economic valuation}) OR TITLE-ABS-KEY ({cost-benefitanalyis}) AND TITLE-ABS-KEY (vietnam) OR TITLE-ABS-KEY (vietnamese)) AND PUBYEAR > 2004 AND (EXCLUDE (SUBJAREA , "medi") OR EXCLUDE (SUBJAREA , "bioc") OR EXCLUDE (SUBJAREA , "engi") OR EXCLUDE (SUBJAREA , "immu"))

Annex 2

Figure 1: Search and screening process for Kenya

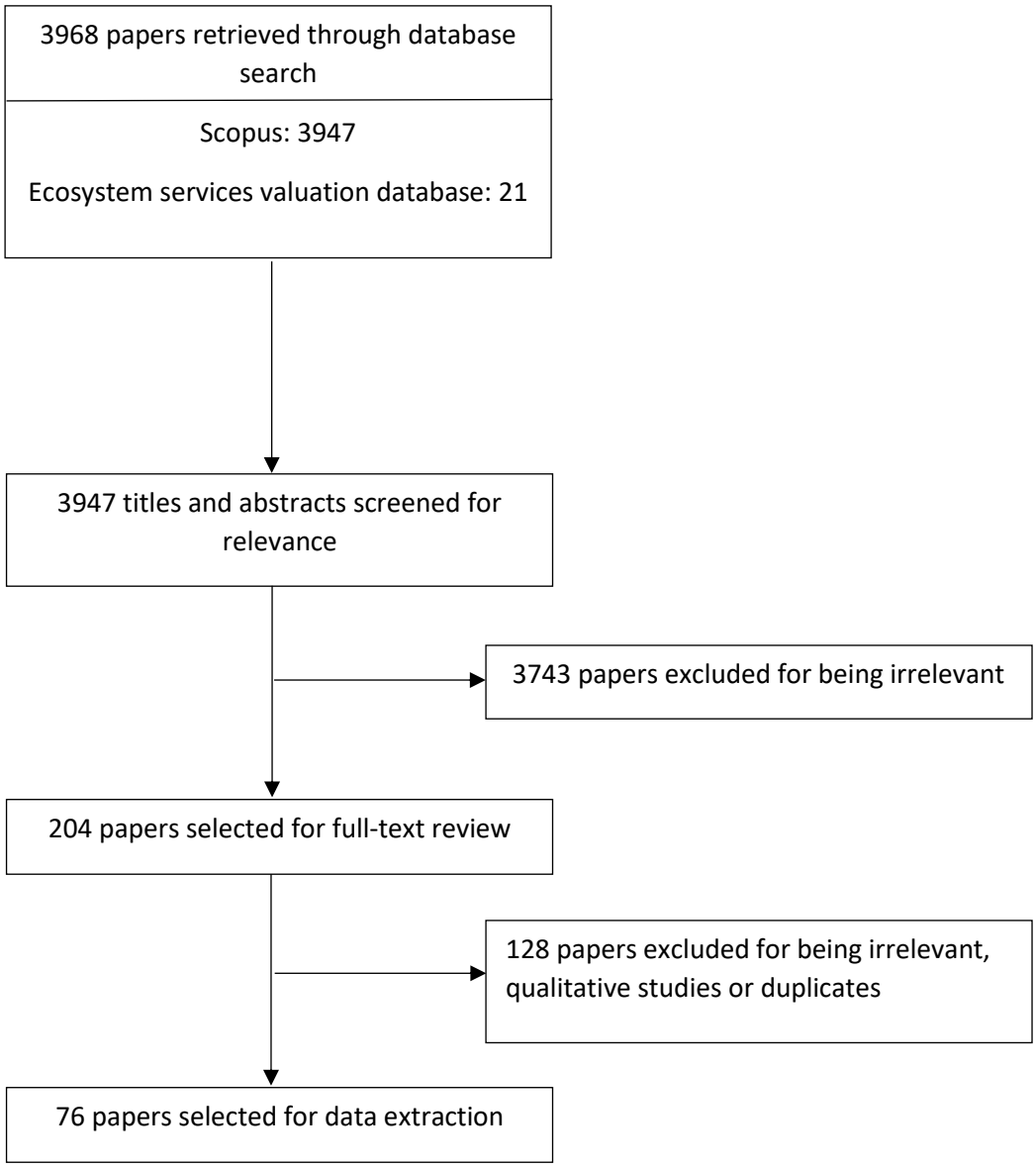

Figure 2: Search and screening process for Vietnam