**Results**

***Macroeconomic analysis***

*Rate of forest loss response*

Models revealed that there were no strong effects of the macroeconomic predictors on forest loss between 1993 and 2015 (Figures Sx – Sx). For each predictor set there were between 5 and 28 models in the top model set and final coefficients were calculated using full averages ( Tables Sx – Sx , Burnham and Anderson, 2007). The largest effects were from two of the control variables (population density, time). The largest effect overall was for population density with a one-year time lag (full averaged coefficient = -632.9, SE = 64.8, Table Sx). The largest effect excluding control variables was for agricultural proportion of GDP (full averaged coefficient = -14.9, SE = 7.9) suggesting that there is a small reduction in the rate of forest loss as the contribution of agriculture to national GDP increases, although this effect is very weak (Figure Sx, Table Sx) and is not considered definitive.

*New economic land concession response*

A greater number of effects were revealed in the macroeconomic analysis with new economic land concession allocation as the response. The largest effect was for the economic control variable population density, where there were very strong negative effects across all time lags (rate ratios for one-year lag = 0.012, two-year lag = 0.002, three-year lag = 0.0005, Table x), indicating that new ELCs do not get allocated in areas of high human population density. The largest overall effect excluding control variables was for changes in agricultural proportion of GDP with no time lag and a one-year time lag (no time lag rate ratio = 1.310, and one-year time lag rate ratio = 1.284, Table X, Figure X). From an economic perspective there were positive relationships between the allocation of new ELCs and increases in the agricultural proportion of GDP and increases in foreign direct investment (one-year time lag rate ratio = 1.004, Table X, Figure X). These effects suggest ties between both the development of new industrial-scale concessions and the growth of the agricultural sector, and the injection of foreign wealth into the sector via the purchasing of concessions by international companies. For example, when the agricultural sector’s proportion of national GDP decreases by 3% in a given year relative to the previous year, the number of new ELCs allocated that year is predicted to be approximately 2, whereas when the sector’s proportion of national GDP increases in a given year by 1% relative to the previous year, the number of new ELCs is predicted to be 6. When the amount of foreign investment decreases by approximately $10 million relative to the previous year, the number of new ELCs one year later is predicted to be 3. Conversely, when foreign investment in a given year increases by approximately $300 million relative to the previous year, then one year later the number of new ELCs is predicted to be 10. The one-year time lag of the effect of foreign investment suggests that it takes approximately one year from the time of investment for a company to see the creation of their land concession. There was also a positive relationship between new ELC allocation and increases in development flows to the environment sector (no time lag rate ratio = 1.031). This suggests that in the short-term, investments into the environment sector via development funding (predominantly from international donors) does not reduce the number of new ELC allocations.

There was a negative relationship between new ELC allocation and increases in per capita GDP (one-year time lag rate ratio = 0.985 and two-year time lag rate ratio = 0.974, Table X, Figure X). The reduction in ELC allocation as GDP increases, over a period of one and two years, potentially suggests that there is a positive economic effect of ELCs. New concessions inject money into the national economy at various scales, for example at the national level via taxes to the government, and to the local level via employment opportunities and infrastructure development. Thus, as the economy grows, the need for new ELCs diminishes. For example, when GDP per capita in a given year falls by approximately $6 relative to the previous year, the number of new ELCs is predicted to be 8, whereas when the GDP per capita rises in a given year by approximately $60 relative to the previous year, the number of new ELCs predicted is only 3.

The largest effect within the commodity set was for the change in market price of rice in the same year as the response (no time lag) with a rate ratio of 1.009 (Table X). There were further strong positive relationships between the changes in the market price of rubber (no time lag rate ratio = 1.001), the changes in the non-food production index (one-year time lag rate ratio = 1.007), and changes in the market price of sugar (two-year time lag rate ratio = 1.009). Economic land concessions in Cambodia are predominantly agro-industrial concessions, and therefore the positive relationships between the market price of agricultural commodities and new ELC allocations is not surprising. Rubber and rice are the most valuable market commodities within the variable set, and we can see this reflected in the model; if rubber market prices do not change between years *t* and *t+1* then approximately four new ELCs are predicted in year *t+1*, whereas if the price of rubber changes by $1500/ton in year *t*, then approximately 29 new ELCs are predicted in year *t+1*. Similarly, if there is no change in the market price of rice between two given years, then approximately five new ELCs are predicted. If the market value increases by $300/ton then in year *t+1* then approximately 80 new ELCs are predicted. Interestingly the effect of changes in sugar price were weak when there was no time lag (Figure X), but the effect was stronger when both a one-year and two-year time lag were introduced.

Negative relationships.

Use point estimates / point predictions – use predict on low x value and high x value to get the resulting y value. Pick x values that are of interest, or current, or relevant for some reason. Can come back to these values in the discussion.

Don’t forget to talk about the macroecon models with forest change as the response. Explain that there were no significant results and to see the SI.

Need to add a column to the results tables called “Rate ratios” which are the exp(coeff). These are the multiplicative terms used to calculate the change in y when x increases by 1 unit.

**Table 3. Parameter coefficients, standard errors, and rate ratios from the top model(s) in the macroeconomic analysis with rate of economic land concession allocation response. Missing values denote predictor variables that were not selected in the top model(s) for that lag period.**

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | ***No time lag*** | | |  | ***1 year time lag*** | | |  | ***2 year time lag*** | | |
| **Variable** | **Coefficient** | **SE** | **Rate ratioa** |  | **Coefficient** | **SE** | **Rate ratioa** |  | **Coefficient** | **SE** | **Rate ratioa** |
| ***Macroeconomic*** |  |  |  |  |  |  |  |  |  |  |  |
| GDP | - | - | - |  | -0.01500 | 0.00340 | 0.985 |  | -0.02600\* | 0.00390 | 0.974 |
| Agricultural proportion of GDP | 0.27000 | 0.07000 | 1.310 |  | 0.25000 | 0.06600 | 1.284 |  | -0.03400\* | 0.07600 | 0.967 |
| Development flows - agriculture | - | - | - |  | - | - | - |  | -0.00005\* | 0.00020 | 1.000 |
| Development flows - environment | 0.03100 | 0.00400 | 1.031 |  | - | - | - |  | -0.00260\* | 0.00450 | 0.997 |
| Foreign direct investment | - | - | - |  | 0.00360 | 0.00050 | 1.004 |  | 0.00040\* | 0.00060 | 1.000 |
| Population density | -4.43000 | 0.85000 | 0.012 |  | -6.09000 | 0.81000 | 0.002 |  | -7.68000\* | 0.95000 | 0.000 |
| Forest remaining | -0.00030 | 0.00004 | 1.000 |  | -0.00004 | 0.00004 | 1.000 |  | 0.00004\* | 0.00005 | 1.000 |
| ***Commodity / production*** |  |  |  |  |  |  |  |  |  |  |  |
| Change in median market price - corn | -0.00330 | 0.005697 | 0.997 |  | 0.00704\* | 0.00647 | 1.007 |  | -0.00365\* | 0.00329 | 0.996 |
| Change in median market price - rice | 0.009324 | 0.00198 | 1.009 |  | -0.00429\* | 0.00272 | 0.996 |  | 0.00004\* | 0.00058 | 1.000 |
| Change in median market price - rubber | 0.001247 | 0.00024 | 1.001 |  | 0.00019\* | 0.00022 | 1.000 |  | -0.00004\* | 0.00009 | 1.000 |
| Change in median market price - sugar | -0.00005 | 0.001931 | 1.00 |  | 0.00708\* | 0.00127 | 1.007 |  | 0.00877\* | 0.00124 | 1.009 |
| Non-food agricultural production index | -0.00995 | 0.00175 | 0.990 |  | 0.00672\* | 0.00264 | 1.007 |  | -0.00149\* | 0.00203 | 0.999 |
| Crop production index | - | - | - |  | 0.00042\* | 0.00144 | 1.000 |  | -0.00328\* | 0.00427 | 0.997 |
| Total production from forestry | - | - | - |  | 0.00000\* | 0.00000 | 1.000 |  | 0.00000\* | 0.00000 | 1.000 |
| Forest remaining | -0.00014 | 0.00002 | 1.000 |  | -0.00017\* | 0.00003 | 1.000 |  | -0.00013\* | 0.00003 | 1.000 |
| ***Producer prices*** |  |  |  |  |  |  |  |  |  |  |  |
| Producer price of corn | 0.00415 | 0.00355 | 1.004 |  | 0.01093\* | 0.00240 | 1.011 |  | 0.00014\* | 0.00081 | 1.000 |
| Producer price of rice | -0.02465 | 0.00436 | 0.976 |  | 0.00452\* | 0.00564 | 1.005 |  | 0.01258\* | 0.00474 | 1.013 |
| Producer price of rubber | 0.03424 | 0.00401 | 1.035 |  | -0.00075\* | 0.00228 | 0.999 |  | -0.00431\* | 0.00467 | 0.996 |
| Producer price of sugar | 0.00004 | 0.00010 | 1.000 |  | 0.00016\* | 0.00018 | 1.000 |  | 0.00000\* | 0.00006 | 1.000 |
| Producer price of cassava | 0.00032 | 0.00123 | 1.000 |  | 0.00006\* | 0.00076 | 1.000 |  | -0.01791\* | 0.00214 | 0.982 |
| Forest remaining | -0.00023 | 0.00002 | 1.000 |  | -0.00015\* | 0.00002 | 1.000 |  | -0.00013\* | 0.00002 | 1.000 |

\* Coefficients derived from full averaging of models within dAIC < 6.

A Rate ratio = exp(coefficient)

Chart

Description automatically generated

**Figure 1. Modelled relationships between economic predictors and the allocation of new economic land concessions in Cambodia between 1993 – 2015. Top row: no time lag between predictor and response; middle row: 1-year time lag between predictor and response; bottom row: 2-year time lag between predictor and response.**

A picture containing diagram

Description automatically generated

**Figure 2. Modelled relationships between commodity price predictors and the allocation of new economic land concessions in Cambodia between 1993 – 2015. Top two rows: no time lag between predictor and response; third row: 1-year time lag between predictor and response; bottom row: 2-year time lag between predictor and response.**

Diagram, engineering drawing

Description automatically generated

**Figure 3. Modelled relationships between producer price predictors and the allocation of new economic land concessions Cambodia between 1993 – 2015. Top row: no time lag between predictor and response; middle row: 1-year time lag between predictor and response; bottom row: 2-year time lag between predictor and response.**

**Table 4. Model outputs from the top models from the socioeconomic analysis. Outputs are for the commune-level analysis and the province-level analysis.**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Variable** | **Variance** | **Std.Dev** | **Coefficient** | | **SE** |
| ***Commune-level final model*** |  |  | |  |  |
| *Random effects* |  |  |  | |  |
| Commune (intercept) | 10.4500 | 3.2334 | - | | - |
| Year/Commune (slope) | 0.0046 | 0.0680 | - | | - |
| Province (intercept) | 6.7730 | 2.6025 | - | | - |
| Year/Province (slope) | 0.0005 | 0.0220 | - | | - |
| *Fixed effects* |  |  |  | |  |
| Intercept | - | - | -4.6240 | | 0.5620 |
| Population density | - | - | -7.5140 | | 1.1270 |
| Mean elevation | - | - | 1.0510 | | 0.1220 |
| Distance to In'tl border | - | - | 0.5805 | | 0.2036 |
| Distance to Provincial capital | - | - | 0.6929 | | 0.1114 |
| ELC presence | - | - | 0.0000 | | 0.0025 |
| PA presence | - | - | 0.0093 | | 0.0143 |
| ***Province-level final model*** |  |  |  | |  |
| *Random effects* |  |  |  | |  |
| Province (intercept) | 1.1762 | 1.0845 | - | | - |
| Year/Province (slope) | 0.0058 | 0.0765 | - | | - |
| *Fixed effects* |  |  | - | | - |
| Intercept | - | - | -2.9900 | | 0.4497 |
| Males in school (low) | - | - | 0.0051 | | 0.0019 |
| Distance to school (low) | - | - | -0.0174 | | 0.0022 |
| Mean elevation (low) | - | - | -0.0223 | | 0.0024 |
| Distance to border (low) | - | - | 0.0061 | | 0.0019 |
| Distance to Prov capital (low) | - | - | -0.0072 | | 0.0019 |
| Presence of economic concessions (1) | - | - | 1.9974 | | 0.4090 |
| Presence of PAs (1) | - | - | 2.8063 | | 0.4965 |

Chart, scatter chart

Description automatically generated

**Figure 4. Predicted relationships (red lines) between socioeconomic variables and forest cover in Cambodia between 2007 – 2012 from the top commune-level model. Predictions are ‘global’ i.e., all random effects were set to their mean values, and thus predictions are not for any specific commune. Black dots are the raw data points of each predictor versus forest cover.**

Diagram, shape, arrow

Description automatically generated

**Figure 5. Predicted relationships between population density and forest cover within Cambodian provinces between 2007 – 2012 using the top commune-level model. Faded grey lines are the predictions for each individual commune within each province. Black lines are the mean provincial predictions, which were computed using the 50% quantile from all commune predictions. Plot panels have non-standard y axis ranges.**

A picture containing diagram

Description automatically generated

**Figure 6. Predicted forest cover within each Cambodian province given high and low levels of school attendance (males aged 6 – 24 in school) from the top province-level model. All other variables in the model were set to their reference level (distance to school = low, elevation = low, distance to international border = low, distance to provincial capital = low, economic land concession = yes, protected area = yes).**

A picture containing diagram

Description automatically generated

**Figure 7. Predicted forest cover within each Cambodian province given high and low distances to the nearst school from the top province-level model. All other variables in the model were set to their reference level (school attendance = low, elevation = low, distance to international border = low, distance to provincial capital = low, economic land concession = yes, protected area = yes).**

Socioecon models – report marginal and conditional R2