Modeling Carbon Sequestration at Millennium Village Sites in East Africa

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Introduction

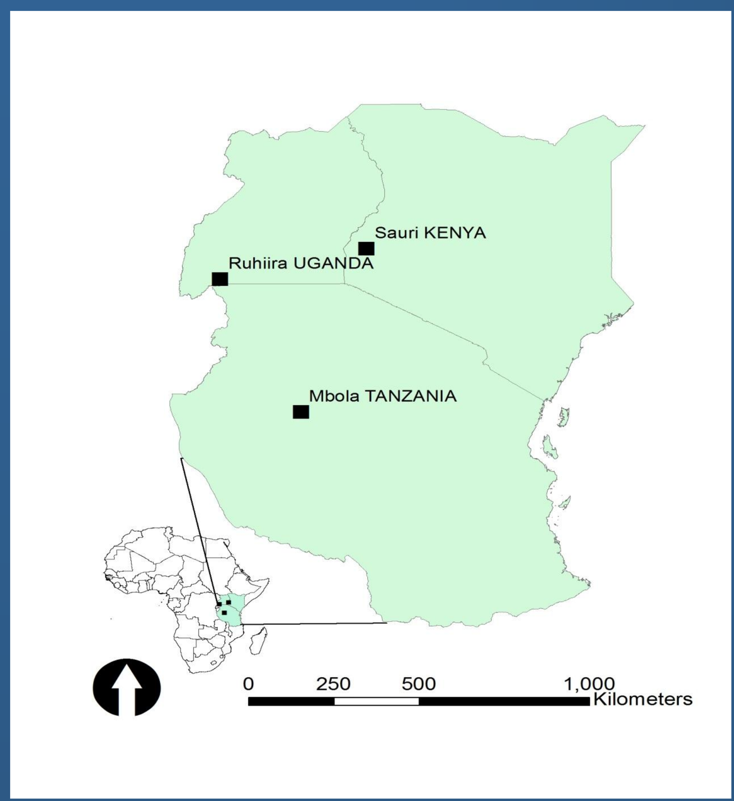
With the prospect of rapid and irreversible anthropogenic climate change looming, the urgency of CO_2 emission reduction is apparent. Accounting for 15-17% of annual greenhouse gas emissions, deforestation and forest degradation are a substantial source of carbon emissions, especially in the developing world (Harvey et al., 2010).

To curb these emissions, the UN has devised a program known as Reducing Emissions from Deforestation and forest Degradation (REDD), designed to provided a financial incentive to encourage landowners to pursue less carbon intensive land management. Based on the market price of carbon sequestered within a given area, REDD carbon contracts would provide payment to landowners based on emission reduction on their land.

This method would be especially effective in the developing world, where deforestation is rampant and even low carbon prices could provide valuable income. Though no REDD program currently exists, establishing it in the developing world will require a mobilization of resources from the developed world and solutions to a few technical hurdles (UNFCC, 2009).

One such hurdle, and the focus of this research, is a method for efficiently and accurately estimating carbon sequestration in a landscape. In many REDD pilot programs; obtaining biomass and carbon stock estimates for the study area has been difficult and at times unsuccessful. The lack of existing data in many developing countries, coupled with the costly, time consuming, and technical nature of data collection make the task difficult (Harvey et al., 2010). It is imperative that a new method for carbon sequestration is developed for to make REDD a reality.

Methods



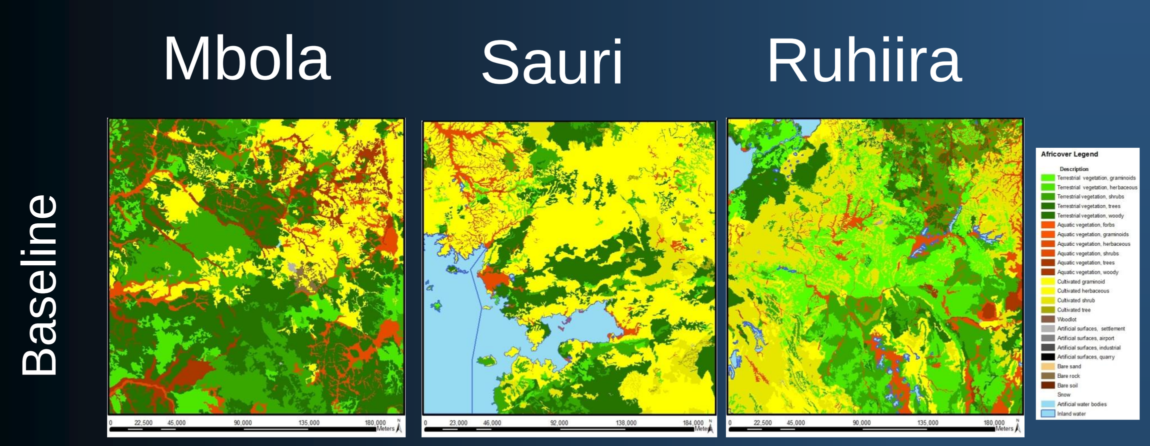
The three villages in East Africa to be examined in this study.

Previous studies have used a spatially explicit modeling toolset, Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST), to estimate the volume and value of carbon sequestration (Nelson et al., 2009). Using land use/land cover maps, coupled with biomass and soil carbon stock estimates for each LULC class, the model provides Tier 1 outputs for current carbon sequestration. More sophisticated outputs are produced by incorporating future land use projections for future carbon sequestration or economic variables (price of carbon and market discount rate) for valuation (Tallis et al. 2010).

The areas chosen to evaluate this model are three Millennium Village sites in East Africa: Mbola, Tanzania; Sauri, Kenya; and Ruhiira, Uganda. These three villages were selected because they represent various stages in a deforestation continuum, from a deforestation front, to complete deforestation to a reforestation front. The baseline land cover dataset that will be used for modeling in InVEST is provided by Africover. For the most part, existing geographical resources for Sub-Saharan Africa are sparse or low resolution. Africover, trained from 30m landsat, was selected as it provides continuous coverage for all three countries being examined. This was compared at the village scale to a higher resolution LULC map developed from a 2.4m Quickbird image.

All carbon pool data for the LULC categories in Africover were drawn from relevant literature. For Quickbird, biomass measurements from Mbola were used as pools data.

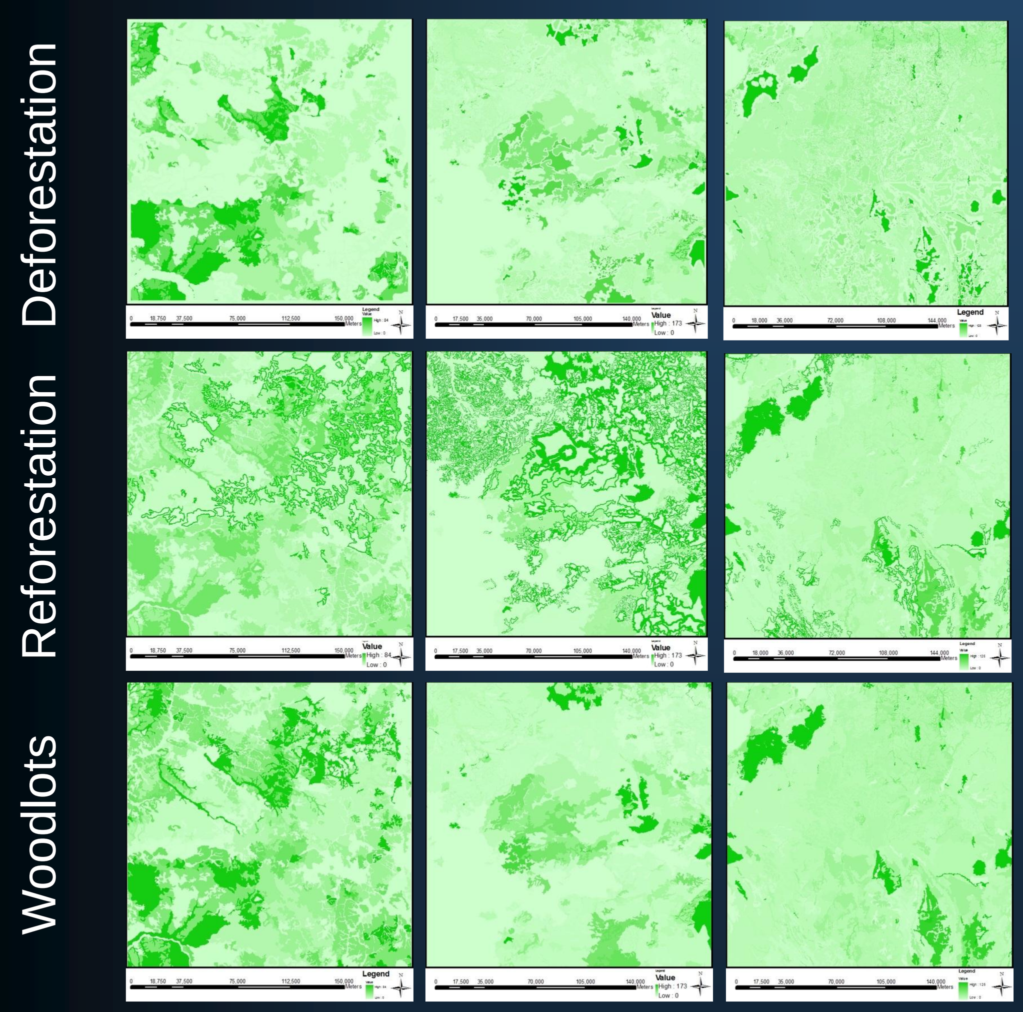
Biomass



Figures 1-3. Baseline Africover maps for the areas surrounding each site. Each map is 200km by 200km..

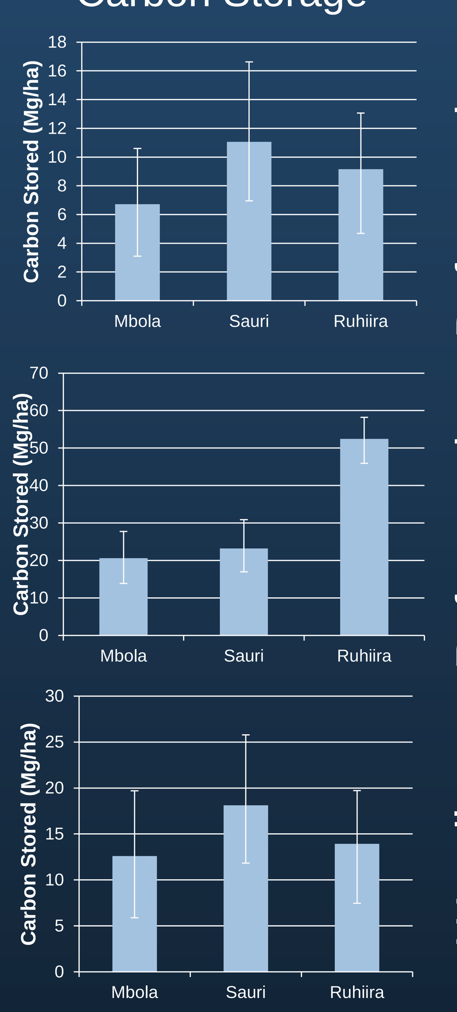
The first InVEST run established future biomass carbon storage for each LULC change scenario.

Future Biomass Carbon



Figures 7-15. Total carbon stored in the landscape surrounding each village for the three land cover change scenarios. Dark green indicates high carbon storage.

Mean Biomass Carbon Storage



Figures 16-18. Comparisons of mean carbon storage for each scenario. Error bars represent high and low model runs based on carbon pool ranges.

Biomass and Soil - Mbola

The second InVEST run sought to evaluate the relative importance of each carbon pool type. Sequestration maps were created for biomass only and biomass along with soil data from FAO. The charts in the middle compare average values between the two.

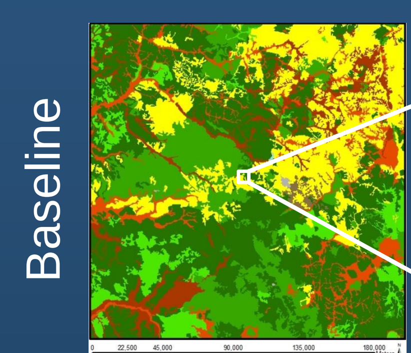
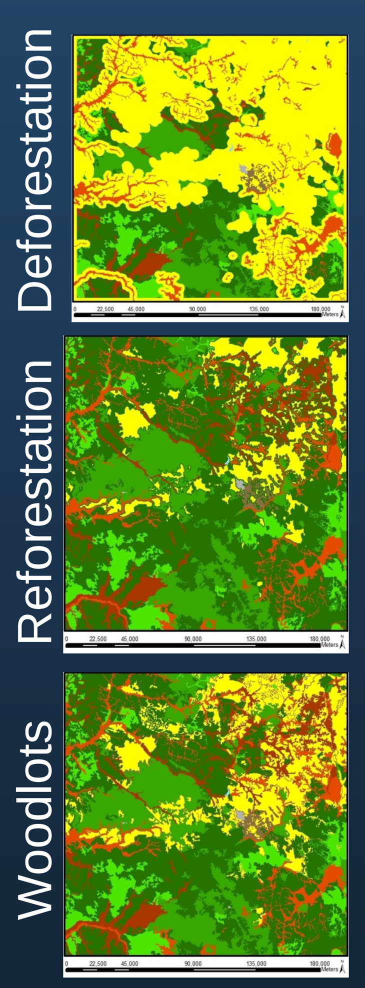


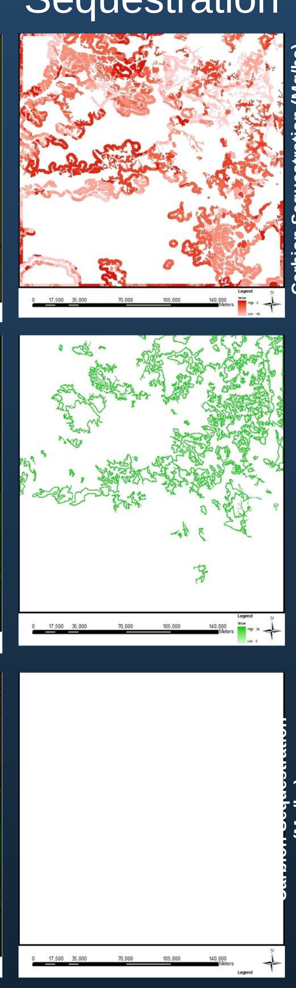
Figure 4. Baseline Africover map for the area surrounding Mbola. The map is 200km by 200km.

Scenario



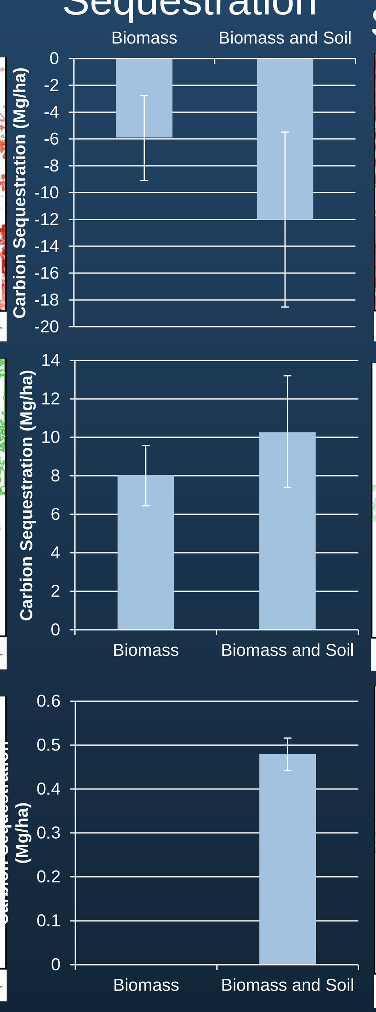
Figures 19-21. Africover maps of each scenario created using a spatial buffer.

Biomass Sequestration



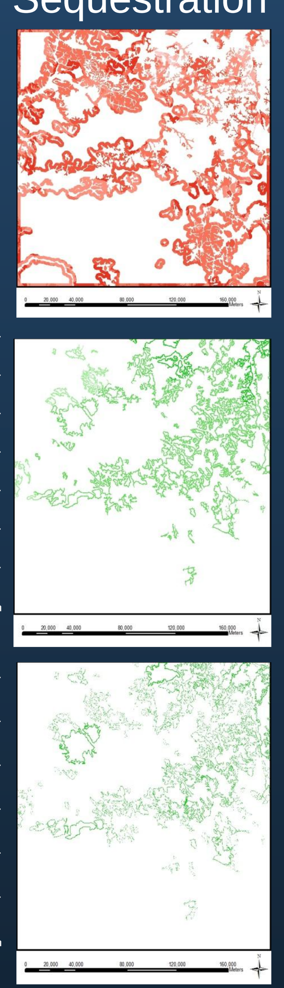
Figures 22-24. Carbon sequestration maps including only biomass pools.

Mean Carbon Sequestration



Figures 25-27. Mean carbon sequestration. Error bars represent high and low model runs based on carbon pool ranges

Biomass and Soil Sequestration



Figures 28-30. Carbon sequestration maps including biomass and soil pools.

High Resolution Biomass and Soil

Africover

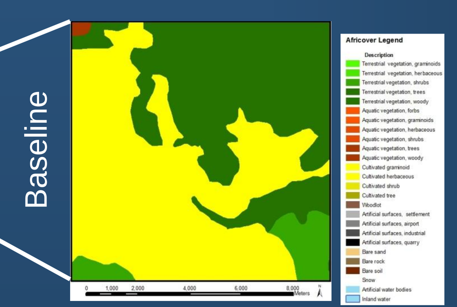


Figure 5. Baseline Africover map for the same extent as the 10km by 10 km Quickbird map. The extent is at the center of the 200km village vicinity Africover map.

The third InVEST run examined the importance of spatial resolution at a village scale. Africover was run through InVEST at 20m resolution. The high resolution Quickbird LULC maps were run at 1m resolution. Actual biomass values from Mbola were used for the Quickbird, as opposed to literature values for Africover.

Quickbird

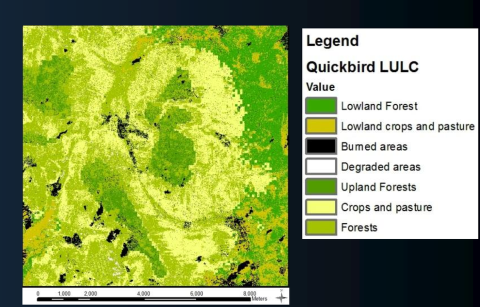
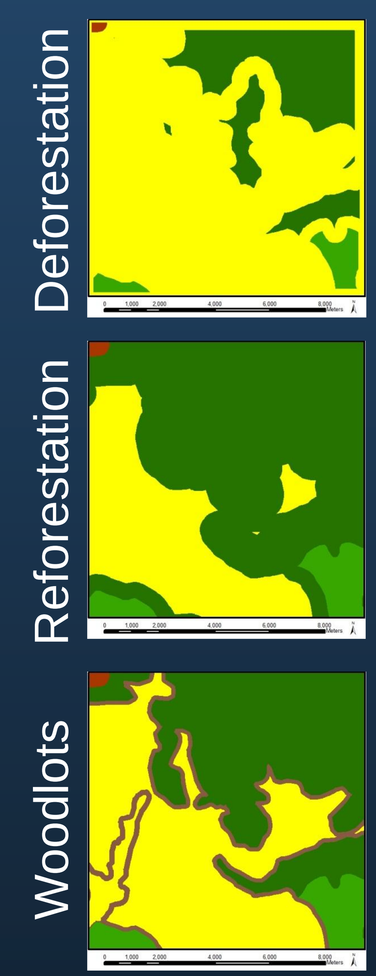


Figure 6. LULC map trained from Quickbird imagery using LDSF data collected in Mbola. The map is 10 km by 10km.

Scenario

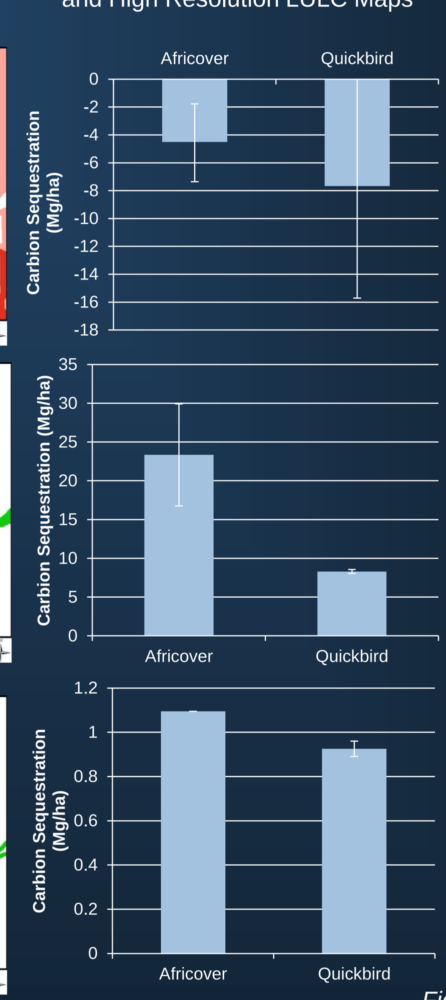


Figures 31-33. Africover maps of each scenario clipped to Quickbird extent.

Sequestration

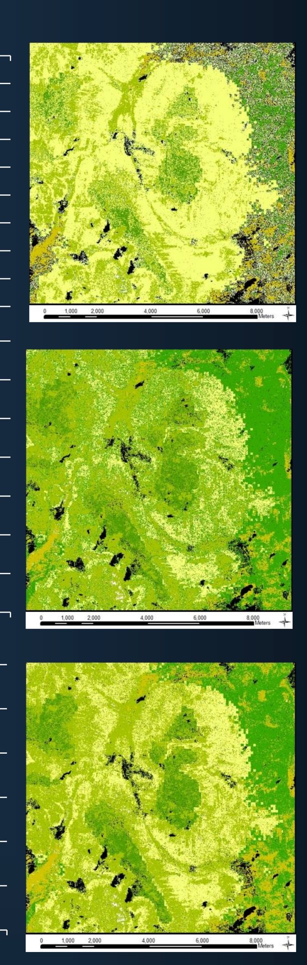
Figures 34-36. Sequestration maps for Afrricover.

Mean Carbon Sequestration for Low and High Resolution LULC Maps



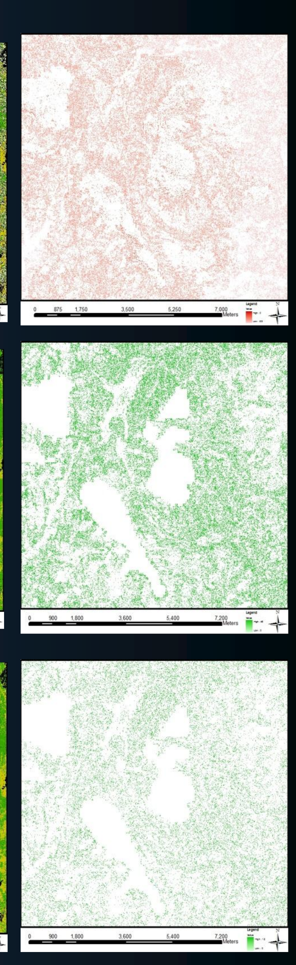
Figures 37-40. Mean carbon sequestration. Error bars represent high and low model runs based on carbon pool ranges

Scenario



Figures 41-43. LULC maps created by converting nearest pixels to a different land cover class.

Sequestration



Figures 44-46. Maps of carbon sequestration from Quickbird LULC.

Discussion

In the first InVEST run, Sauri had the highest future biomass carbon in both the deforestation and woodlot scenarios. Ruhiira had the most carbon in the reforestation scenario. This result is an illustration of the land cover characteristic to the area around Sauri, which is already heavily deforested. Over half of the landscape is dominated by cultivated areas, as such deforestation does not provide a drop as precipitous as in Mbola and Ruhiira. In all three scenarios, Mbola had the lowest biomass carbon storage. This is likely the result of by lower biomass carbon pool values for the less dense Miombo woodlands that dominate more than 25% of the 200km Mbola map.

The second InVEST run illustrated the necessity of including soil organic and inorganic carbon in any carbon sequestration model. Though the patterns of sequestration seen in the maps are spatially similar, as they were draw from the same land cover change scenario, the amount of carbon sequestered when soil is included is quite a bit larger when soil is included, especially in the deforestation and woodlots scenario.

The third InVEST run sought to evaluate the importance of spatial resolution in modeling carbon sequestration. The Africover maps, were run through InVEST at a 20m resolution. The Quickbird LULC was modeled at 1m. As such, the spatial differences in sequestration, as illustrated in the maps for identical scenarios, is very different. The third run also shows the importance of using ground-truthed biomass values. In each scenario, Africover overestimates sequestration and underestimates emission, with huge error in either direction. Quickbird, with the exception of the deforestation scenario, is vastly more accurate as shown by the error bars representing high and low biomass estimate runs. When evaluating a landscape for potential carbon contracting, the most accurate and conservative methods are desired.

Conclusion

The three model runs, each incorporating three future land cover scenarios, indicate that InVEST is a useful tool for preliminary evaluations of carbon sequestration in a landscape, provided sufficient inputs are used. A carbon pools dataset that includes dynamic soil carbon and ground-truthed biomass numbers, coupled with high resolution LULC datasets make InVEST an extremely powerful toolset for evaluating the volume and value of carbon sequestration.

References

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Tallis, H.T., Ricketts, T., Nelson, E, Ennaanay, D.,. Wolny, S, Olwero, N Vigerstol, K., Pennington, D., Mendoza, G.,.Aukema, J., Foster, J., Forrest, J., Cameron, D, Lonsdorf, E., Kennedy, C. 2010. InVEST 1.004 beta User's Guide. The Natural Capital Project, Stanford.

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