AMERICAN CARBON REGISTRY

AFOLU TECHNICAL COMMITTEE RECOMMENDATION

Issue Under Review:	Proposed modification to ACR *Methodology for Afforestation and Reforestation of Degraded Land (version 1.0, March 2011),* to include Forest Vegetation Simulator (FVS) as an approved quantification tool
Issue Number:	2012-001
Entity Requesting Review:	US Forest Service - Forest Management Service Center
Date Presented to Committee:	September 4, 2012
Committee Members Reviewing:	Neil Sampson (Chair), Dr. Tim Robards, Dr. Gordon Smith
Earlier Actions (if applicable):	None
Recommendation:	Return to USFS for response

Summary of Issue under Review

The ACR *Methodology for Afforestation and Reforestation of Degraded Land* was approved in March 2011. It is based on CDM methodology ACM0001 v5, with additional text for accounting for wood products. This earlier methodology modification was proposed by TREES Forest Carbon Consulting and approved by the ACR AFOLU Technical Committee in March 2011.

In a second modification, the US Forest Service - Forest Management Service Center proposes to modify the methodology by making the Forest Vegetation Simulator (FVS) model an approved quantification tool. According to the Forest Service proposal:

> *"The Forest Vegetation Simulator (FVS) is the USDA Forest Service's national forest growth and yield model. It is a system of highly integrated analytical tools used throughout the United States by government agencies, industry, educational institutions, private landowners, and others. It uses standard forest inventory data to assess current forest conditions, as well as estimate future forest conditions. It estimates carbon quantities in various pools (such as live trees and dead trees, litter and duff, down dead wood, and wood products). Virtually any management action can be included in a simulation. It is a well-supported model with a helpdesk for users and trainings offered annually.*
>
> *For those doing carbon analyses, FVS is useful in two ways – it is a powerful forest growth model for making future carbon projections, and it has built-in carbon calculations (quantifying the carbon in various pools based on inventory data). The latter feature allows FVS to be used as a carbon inventory compiler at the stand to landscape level. FVS is currently being used to simulate stand development and management for projects submitted under the American Carbon Registry (ACR) afforestation/reforestation methodology, however this methodology currently does not accept the FVS quantification of carbon so additional calculations are required. Many of the calculation methods and assumptions in "Methodology for Afforestation and Reforestation of Degraded Land, Version 1.0, March 2011" are either identical or very*

similar to the carbon calculations in FVS. We propose adding FVS as an accepted quantification tool under this methodology.

Blending FVS output into the current methodology is cumbersome and redundant, and the likelihood of computational errors is high. It would be more efficient and less error-prone to allow the FVS carbon quantification to be used directly with the methodology. This approach could also make these analyses more easily replicable and consistent across projects. An applicant could do two FVS simulations for the ex ante calculations – one simulation for the baseline and one for the project scenario – to estimate carbon stock changes over time under both scenarios and use this information with minimal manipulation to meet the methodology standards. A third simulation could be done for the ex post calculations, where FVS is used with field measurement data to estimate carbon solely for the year in which the data were collected."

The Forest Service has provided a revised version of the ACR A/R methodology with the text for FVS shown in track changes. Note that the new equation numbers, and the references to equations by number in the text, have not yet been updated.

Summary of Committee Review and Discussion

The proposed methodology speaks of the FVS as one national model, but this is not exactly accurate. The FVS has several regional variants and two primary biomass models, making it important for project proponents to use an appropriate variant and the most accurate biomass model. These options are not mentioned in the proposed methodology. On page 3, for example, users are urged to use the latest version of the FVS software, but there is no mention of the appropriate variant. It is assumed that all variants are equally accurate in projecting carbon stocks. Is this the case?

In A/R projects, where the initial conditions are without trees, the baseline is calculated on land use conditions, so FVS is not needed or appropriate. Where there are scattered existing trees, they should be removed from the project area or carbon calculations, as the modeling of understocked stands is not reliable in FVS or in other growth and yield models developed for fully-stocked conditions. In FVS, the user selects whether to use the FFE fire model or the Jenkins model as the method of calculating total biomass. The methodology should explain the difference between the two. Based on our experience that the FFE model gives more accurate estimates, we recommend that the methodology make the FFE the default, and that if the project developer wishes to use the Jenkins models, we recommend that the methodology require the project developer to demonstrate that the Jenkins models is more accurate when applied to the project. We also recommend that documentation of the FFE equations be provided to improve transparency of the model.

There are alternate ways to input standing dead data. Should a default be identified, or guidance in how this is to be done? (This may not be as important in A/R as in forest management, as standing dead should probably be ignored in a 40-year A/R project.)

Some pools, such as litter and duff, are derived from habitat or forest type models rather than measured inventory data. If these pools are validated by later measurements, there could be significant "jumps" in pool estimates. Again, this is not as important in A/R as in forest management projects.

Where the FVS is used to compare project conditions or to compare two different projects, the methodology should stress the importance of using identical FVS entry methods and variants.

The FVS model does not seem to be relevant to estimating A/R project baselines. The committee recommends that the methodology be edited to say that in A/R projects the pre-project use is assumed

to prevent natural regeneration of trees and thus no estimates of ingrowth are needed. The committee also recommends that the methodology be edited to say that if there are pre-existing trees within the project area, the project accounting area boundary should be adjusted to exclude the pre-existing trees from the area where sequestration will be counted for credit generation. Excluding pre-existing trees avoids the uncertainty of estimating 40 to 100 years of baseline growth and mortality of pre-existing trees.

The Rebain (2010) reference should be incorporated in the methodology as it describes the underlying models within the FVS.

Committee Decision and Recommendation

While the use of FVS in the methodology for estimating carbon stock change between inventories seems reasonable, there should be some additional guidance as to its proper use, as discussed above. For example, inventory data older than 10 years should not be used as a basis for estimating current carbon stocks.

The use of variants and selection values should be standardized in the methodology, and if the Forest Service recommends default values, those should be incorporated.

The FVS model is not relevant for estimating baselines for A/R projects.

The proponents should edit the language in the methodology to illustrate more clearly how to use FVS correctly and deal with the variants and different settings that the user finds in the program.

For documentation, the methodology should require Project Proponents to provide the .OUT file and all input files for review by ACR and/or the validation/verification body.

References

Rebain, S.A. 2010. The Fire and Fuels Extension to the Forest Vegetation Simulator: Updated Model Documentation. Internal Rep. U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 361.

Specific Comments

The following specific comments from the reviewers informed the Committee's discussion and recommendations and are provided here for the methodology authors' information.

Comments on FVS Request
Timothy Robards, PhD
September 15, 2012

In general I agree with the assertion that using FVS carbon output could reduce analyst time and project cost while reducing chances for error in calculations. I have the following comments that I believe need to be addressed before approval.

1) The primary reference to the underlying models of carbon are found in (Rebain 2010). This document provides detailed information by geographic variant of FVS. Are there any FVS variants that do not meet the minimum quality standards to be included in the protocol?
2) References in the draft protocol are to FVS and not the underlying models. How will software version upgrades be managed? Can backwards compatibility be maintained so that users can take advantage of maintenance releases that may improve growth or mortality models but hold the carbon models constant over time?
3) There are alternative ways to input standing dead data that use decay class or may not use it. What is the protocol standard? Is it ok to use a default of hard snags as occurs initially?
4) There are two primary biomass models that may be used as I understand it, the FFE fire models and the Jenkins models. Which of these is the standard for the protocol?
5) Some pools, such as litter and duff, are derived from habitat or forest type models rather than measured inventory data. This will be validated by actual field measurements. There is a potential for jumps in estimates as plots move from one category to another. If this is a small portion of the total pools it may be negligible.
6) Would it be possible to provide standard keyword settings for the decisions made above to improve clarity?
7) The Rebain (2010) reference should be incorporated as it describes the underlying models.

Comments on Allowing FVS for ACR AR Quantification
Gordon Smith, PhD
19 September 2012

The proposal is to modify the existing ACR Forestry AR Methodology to include use of the FVS model for modeling baseline and project carbon stocks. Pools that may be modeled include live trees (above and belowground), standing dead trees, down dead wood, litter, and carbon in harvested wood products.

There are two types of uses of FVS proposed here. One type of use is to model forest growth. The other type of use is to calculate forest carbon stocks (including harvested wood products) from inventory data. In general, I think the calculation of current stocks is much less problematic than modeling growth.

All forest growth (and harvest scheduling) models are problematic for offset registries. They appear to offer objectivity but often predict implausible outcomes that are hard for validators and verifiers to reject.

The FVS model has several quirks that must be addressed before it should be used to calculate offsets. I'll comment on some of the main quirks in my specific comments below.

I think we should apply the FVS simulator and make sure it is giving reasonable results before we approve it for use by ACR projects (or look at results of other people applying the simulator).

In my opinion, it is reasonable that FVS be used to calculate current year carbon stocks using inventory data from multiple years. I would add the requirement that no inventory data older than 10 years may be used for modeling with-project carbon stocks. "Actual Net GHG Removals by Sinks" would be calculated by subtracting the stock present at the prior offset issuance from the current stock. This would allow use of FVS to get credits issued between forest inventories, and allow inventories to be up to 10 years apart.

The FVS estimates of dead wood stocks have two problematic aspects. One, the model uses stand age to estimate dead wood volume, and dead wood is more a function of disturbance history than stand age. Two, sometimes FVS gives totally implausible estimates of mortality. For example, one set of modeling runs I did with the Central and Southern variants gave mortality estimates that were only slightly less than the live stocks and appeared to be live minus mortality. I think the model should be allowed for predicting decomposition of measured dead wood stocks, but I think it is safer not to allow the model to estimate dead wood stocks.

The model has allometric equations pretty much hard wired. I have not tried to calculate carbon stocks using FVS for a couple years. My recollection is that the allometric equations were quite general, and used diameter and species group as the only inputs for estimating biomass and carbon stock. Perhaps this is not true for the FFE approach. The generic allometric equations and height growth functions produced carbon stock and sequestration estimates that are probably accurate as regional averages, but were quite different from estimates using more site-specific data and equations. I found that FVS significantly underestimated tree heights (and thus underestimated carbon stocks) in productive stands. Presumably project developers will know this and not use FVS to estimate carbon stocks in productive stands.

FVS is proposed to be used for modeling baseline tree growth. Because this is an AR methodology, baseline tree growth must be growth of (a) pre-existing trees, (b) natural in-growth, and/or (c) a baseline rate of afforestation. The ACR Forest Project Standard v2.1 requires that projects have a life of at least 40 years. I don't know any modeler who has checked model results against actual forest conditions who would argue that any forest growth model gives reliable estimates of conditions more than 40 years in the future. Thus, I think pre-existing trees should be excised from the project or monitored. Alternatively, I think it would be reasonable to measure the number of pre-existing trees and their ages, project how much of the project area they would occupy at the end of the project life, and use the most relevant 1605(b) table to estimate change in baseline carbon stock. Regarding natural in-growth, I've found the regeneration estimates of FVS to be the most unreliable part of the whole modeling system. I don't think ACR should allow FVS modeled estimates of natural regeneration. Regarding baseline rates of afforestation, FVS is a tree/stand level model and afforestation should be

quantified by surveying land cover changes. I conclude that FVS is not appropriate for modeling baselines for AR projects.

It might be important to add some limitation on the minimum tree size and/or age for which growth can be modeled for the purpose of calculating offsets. For small trees, such as less than 4" DBH, but especially seedling size trees, I have found FVS to be extremely sensitive to initial conditions, especially crown length. I suggest limiting the use of FVS to trees that are at least 10 cm DBH.

In my opinion, if project monitors project performance (e.g. stocks of carbon in trees, in the case of AR projects) ex ante estimates of future project performance are of little importance. Because these ex ante estimates are not important, project developers should be given wide latitude in how they make projections. In my opinion, at the time of project validation, project developers should be allowed to use FVS to make ex ante estimates of project sequestration.

The draft text requires use of permanent plots. In my opinion, project developers should be allowed the option of using temporary plots.

My understanding is that FVS calculates harvested wood product carbon stocks very similarly to the 1605(b) method. I think it is reasonable to allow the use of FVS to calculate carbon remaining stored in harvested wood products.

Methodology Changes and Justification

Stephanie Rebain
March 11, 2013

The latest version of the methodology incorporates the suggestions from the AFOLU Technical Committee Recommendation.

The primary changes are in section IV at the end of the document. This new section outlines general guidelines for using FVS, including using the latest software, selecting the appropriate variant, using recent inventory data, using a comprehensive dataset for input, regeneration assumptions, biomass calculation methods, using identical settings across simulations, and providing ACR with the FVS main output file as well as input data files used.

Other changes include:

- Limiting the use of FVS for the carbon calculations to only the U.S. FVS variants; variants for outside the U.S. are available, but not maintained by the USFS. As a result, we cannot verify the biomass and carbon calculation methods used in those variants (see the end of section I.1)

- Additional comments about the possibility of using a reduced sample size when running FVS (see section III.2.2)

- Clarification on how to calculate carbon stored in harvested wood products (see section II.5.1.5.A)

One statement that doesn't seem accurate is "The FVS model is not relevant for estimating baselines for A/R projects." If FVS is not used for the baseline, then the scenarios run using FVS can't really be compared against the baseline to calculate differences. As an example of the use of FVS to calculate the baseline, 5 years ago I worked on some analyses where we examined carbon sequestration after various fires around the country. We compared two simulations - a natural regeneration scenario (the baseline) and a planting scenario - to see how carbon storage differed between the two. Had FVS not been used for the baseline, the difference in stored carbon between the planting scenario (run using FVS) and the baseline (calculated in some other way) could be partially due to differences in the methods used to generate the values. A few years ago when I was working with Greg Peters at NFF on a project he was submitting to ACR on the Angeles National Forest, we used FVS to estimate carbon for the baseline as well as the project scenario. In situations like these, and potentially others, it seems appropriate to use FVS for the baseline scenario.

In the response from the committee, it is suggested that removing scattered existing trees from the carbon calculations is necessary because FVS or any other growth and yield model is not reliable for predicting their growth. While FVS was developed primarily for forested conditions, it still makes reasonable predictions for open-grown trees. The changes in carbon due to growth and mortality of existing trees could be significant over time.

In the response from the committee, there are some comments that are targeted at A/R projects or forest management projects, but not necessarily both. For instance, it says "This may not be as important in A/R as in forest management, as standing dead should probably be ignored in a 40-year

A/R project." As we understand it, there is a separate methodology for use with forest management projects. The proposed changes are meant to only apply to A/R projects and not forest management projects.

In response to some of the other comments in the "Summary of Committee Review and Discussion", it cannot be said that all variants are equally accurate in projecting carbon stocks. We do maintain an FVS validation webpage, where past and ongoing validation projects and publications are listed. This validation webpage is http://www.fs.fed.us/fmsc/fvs/documents/validation.shtml.

With regard to the concern about some pools, such as litter and duff, being derived from habitat or forest type models rather than measured inventory data, FVS users have the choice of initializing the litter and duff values using their own measurements or using the model's default estimates based on habitat type, cover type, or forest type. Once the initial values are set, the estimated changes in litter and duff are based on modeled accumulation and decay and typically don't show sudden jumps over time. However, if modeled values are initially used for reporting and then later measured values are used for reporting, there could be a sudden jump.