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04

## INFO BRIEF

# Considering the use of spatial modeling in Forest Reference Emission Level and/or Forest Reference Level construction for REDD+

November 2015

## SUMMARY

This note aims to inform technical staff responsible for forest reference emission level and/or forest reference level (FREL/FRL) construction about the use, and potential added value and/or limitations, of spatial modeling. It explains the underlying concepts that spatial models apply and discusses how FREL/FRL construction could be affected by such models, illustrating their application with country examples. The note concludes that the use of spatial models in FREL/FRL construction is limited and therefore also discusses potential purposes spatial modeling may fulfil in the broader context of REDD+.

## CONSTRUCTING A FOREST REFERENCE (EMISSION) LEVEL

FREL/FRLs are benchmarks for assessing each country's performance in implementing REDD+ activities<sup>1</sup>. FREL/FRLs should be established transparently, taking into account historic data, and adjust for national circumstances<sup>2</sup>. UNFCCC provides modalities for FREL/FRL construction<sup>3</sup>. FAO 2015 and GFOI 2015 discuss FREL/FRL construction and FAO 2014 provides examples of FREL/FRLs proposed by countries. Ideally, a FREL/FRL should reflect the level of future forest emissions

1 UNFCCC, Decision 12/CP.17, par. 7

2 UNFCCC, Decision 4/CP.15, par. 7

3 UNFCCC, Decision 12/CP.17

expected in absence of REDD+ implementation and for this reason countries may be interested in modeling the magnitude and location of future deforestation.

## WHAT IS SPATIAL MODELING?

There are two main aspects associated with modeling future deforestation: 1) the amount of future forest loss and 2) the location of future forest loss. Spatial models are those that address the second aspect. Models addressing the first aspect (amount of future loss) typically involve complex land-use change algorithms fed by assumptions of economic and socio-political developments as (indirect) drivers of deforestation. In the context of FREL/FRLs, countries could consider the use of these types of models—not without challenges—to adjust<sup>4</sup> their FREL/FRL for national circumstances. This information note does not discuss these kind of models, but some challenges when used in FREL/FRL construction are discussed in "Technical considerations for FREL/FRL construction for REDD+ under the UNFCCC" (FAO 2015). Instead, this information note discusses spatial models addressing the second aspect (location of future

4 E.g. countries with high forest cover and low historical deforestation rates may want to propose an upwards adjustment to historical emissions from deforestation to take into account expected future pressures on their forests as a better predictor of future emissions than using only historical data.

forest loss) and their use in FREL/FRL construction. Spatial models obviously need to allocate an amount of change to a specific location but generally the model focusses on the simulation of the location of change, not on the amount of change, which is often an external input or a strongly simplified approximation e.g. a linear trend projection or historical average (e.g. Elz et al 2015, Stan et al 2015). Though these spatial models may be used in combination with models predicting the amount of future forest loss, the discussion in this information note is restricted to modeling the location of future deforestation.

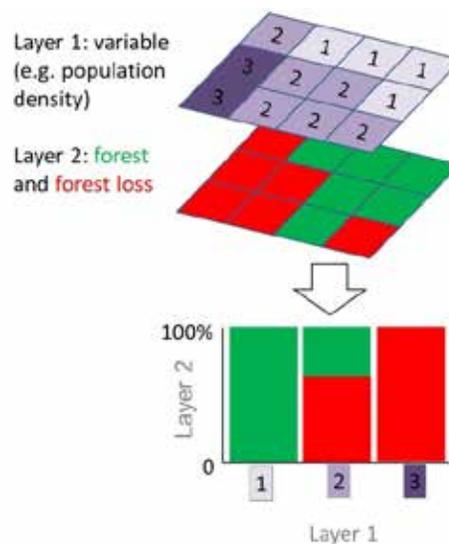
## Underlying principle of spatial models

Spatial models simulating locations of future land use change may perform differently and apply different algorithms, but all are informed by a similar underlying principle: the models compare historical forest loss maps with maps of variables which are thought to relate to deforestation (e.g. distance to roads, soil type, population density). By overlaying these maps, they explore whether deforestation occurs more frequently on locations with specific values in the variable maps (e.g. close to roads) and accordingly they approximate the probability of future deforestation based on this past correlation. Figure 1 gives a simplified demonstration of the underlying principle of spatial models. The minimum input to the model is a forest - non forest map (layer 2 in Fig 1) and at least one (but usually several) variable map (layer 1 in Fig 1). Non-forest in layer 2 should represent forest loss and forest in layer 2 should represent forest persistence (forest remaining forest); other land-uses which do not necessarily represent deforested locations should be excluded from the analysis. By accordingly performing a pixel count per variable class of forest loss versus persistence, the model estimates the likelihood of conversion per variable class (e.g. in Fig 1, there was no loss in class 1; class 2 saw 4 out of 6 pixels being lost or 67%; and the 2 pixels in class 3 were deforested or 100% loss). By accordingly plotting on a graph one can establish if there seems to be an apparent correlation or not: for Figure 1 deforestation seems to increase with the value of layer 1 (though obviously 3 classes is very few to test the hypothesis). Accordingly, all pixels of remaining forest area are assigned a probability of future conversion based on the variable class(es) at which they are located (so in Fig 1 forest located in variable class 2 would have a higher deforestation risk than forest located in variable class 1). The output of

the modeling procedure is a transition potential map (also referred to as probability or suitability for change map, or deforestation risk map) showing the remaining forest and the probability per pixel of conversion.

## Spatial modeling platforms

Several spatial modeling platforms are available which can identify forest areas at increased risk of being



**Figure 1. Graphical display of apparent correlation between forest loss and the values of a certain variable (e.g. population density): a higher value of the variable seems to coincide with more deforestation.**

deforested based on an analysis of locations of past forest loss (more information about specific models is provided in Table 1).

## Predicting locations of future forest loss; an example

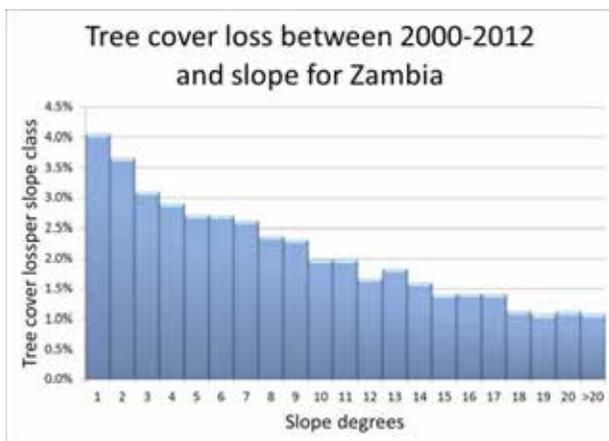
For illustration purposes, a forest loss probability map was created using very coarse data for Zambia taken from publicly available global products <sup>5</sup>. In Zambia, it was observed that in the past forest was lost on locations with high accessibility, high rural population density and low slopes. The correlation between tree

<sup>5</sup> Tree cover loss between 2000-2012 was downloaded from the global Landsat-VCF product (Hansen et al 2013) and combined with Zambia's 2010 forest cover map to create a historic deforestation map to feed into the spatial model. The 2010 forest cover map for Zambia was created by allocating the forest area as reported to the Global Forest Resources Assessment 2010 to the highest 2010 VCF values. The three variables used to predict future locations of deforestation based on correlation in the past were: 1) travel distance to cities with >20,000 people (JRC 2008), 2) rural population density (FAO 2005), and 3) slope (CSI 2012).

**Table 1 Examples of spatial models\***

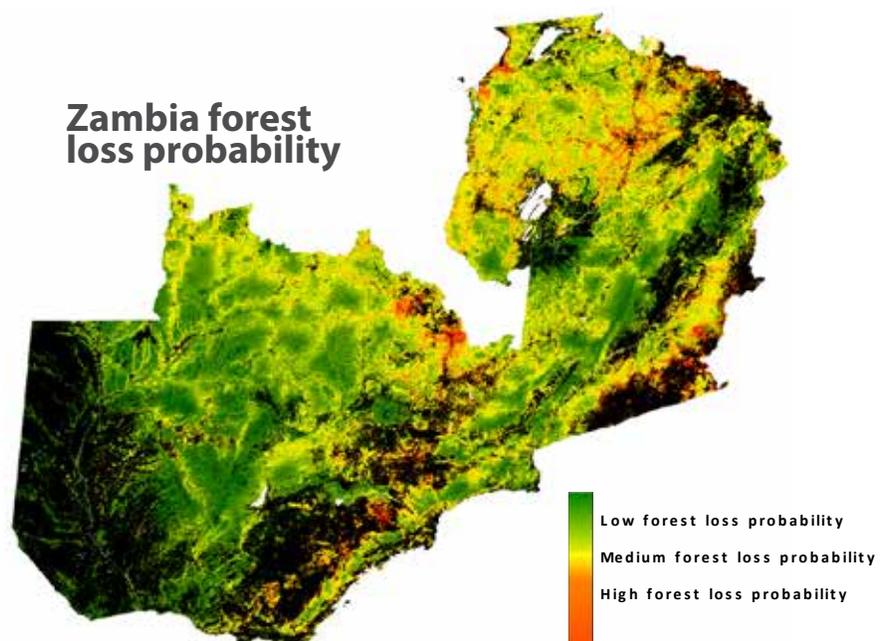
GIS platform	Spatial model	Freely available?	Website
Dinamica EGO	Dinamica EGO	Y	<a href="http://www.csr.ufmg.br/dinamica">www.csr.ufmg.br/dinamica</a>
CLUE	CLUE, CLUE-S	Y	<a href="http://www.ivm.vu.nl/en/Organisation/departments/spatial-analysis-decision-support/Clue/index.asp">www.ivm.vu.nl/en/Organisation/departments/spatial-analysis-decision-support/Clue/index.asp</a>
Idrisi/TerrSet	Land Change Modeler, GEOMOD	N	<a href="http://www.clarklabs.org">www.clarklabs.org</a>
ArcGIS 10.2+	Land Change Modeler for ArcGIS	N	<a href="http://www.clarklabs.org/products/Land-Change-Modeler-Overview.cfm">www.clarklabs.org/products/Land-Change-Modeler-Overview.cfm</a>

\* Some of these models have options to simulate the quantity of future forest change in a simplified manner but the focus of these models tends to be on the expected location of future change.



**Figure 2. Slope as a potential predictor of future deforestation. The apparent relationship between tree cover loss and slope provides an indication future deforestation may more likely occur on the lower slopes (i.e. lower degrees).**

cover loss and slopes is illustrated in Figure 2. The three variable maps and a map with locations of current tree cover and tree cover loss are entered into a spatial model<sup>6</sup>. The resulting forest loss probability map is displayed in Figure 3 where the red areas concern the most accessible forest, at low slopes and with a high concentration of rural people living nearby.



**Figure 3. Map showing the risk of deforestation or forest loss probability based on travel distance, rural population density and slope: the coloured areas on this map represent forest in 2000, with low to high deforestation probability. The black areas represent non-forest land, white areas are water bodies.**

<sup>6</sup> The modeling platform used was Idrisi’s GEOMOD.

When a certain amount of future deforestation (e.g. historical average annual deforestation) is entered in a spatial model, the model would convert the highest forest loss probability values (i.e. the red areas in Figure 3).

Further examples of the use of spatial modeling are found in Elz et al (2015), Stan et al (2015), Galford et al (2014) and the 2014-2015 FREL submissions to the UNFCCC from Colombia and Guyana.

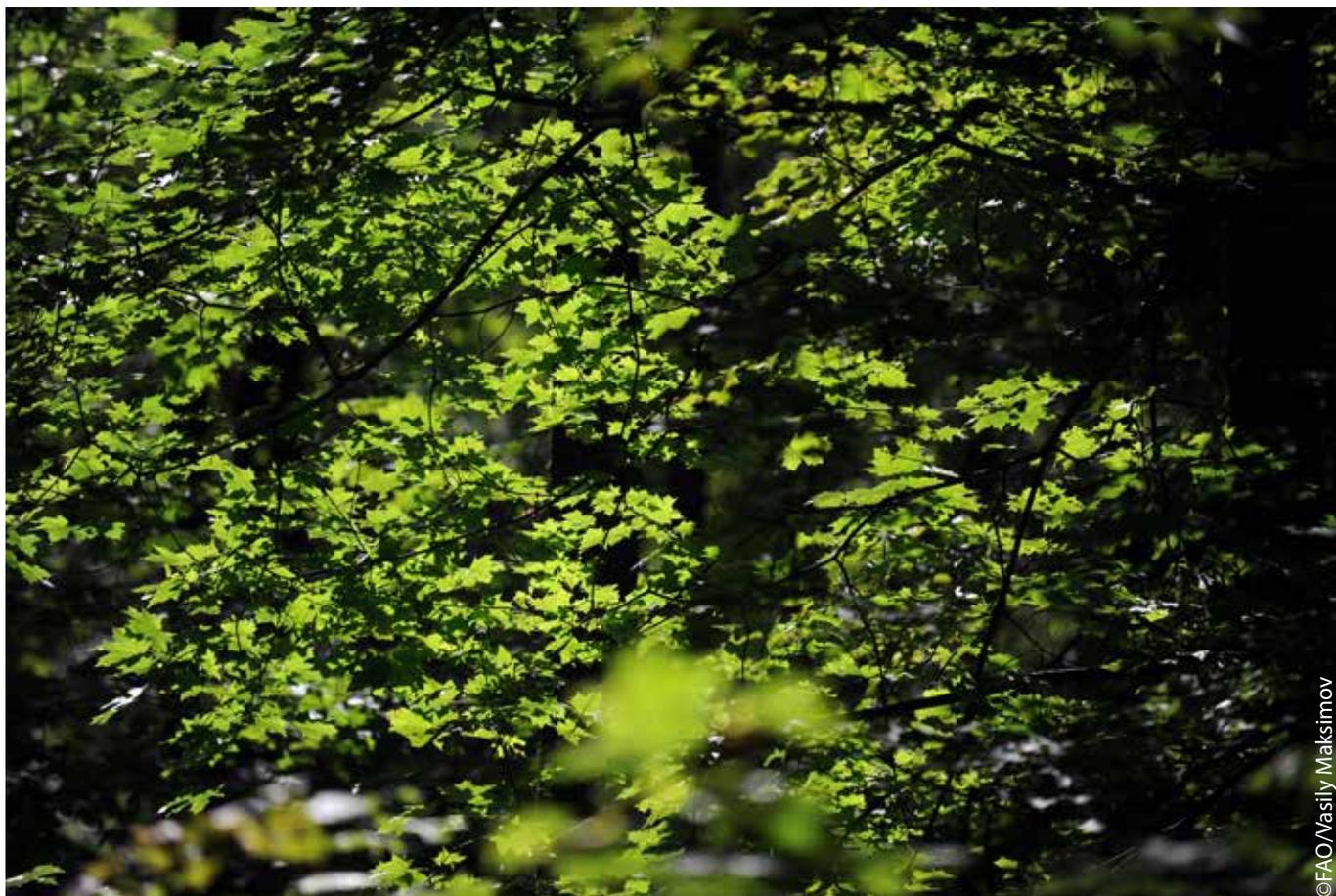
### The use of spatial models in FREL/FRL construction

The spatial models described in this note simulate the expected location of future deforestation. As such, their use for FREL/FRL calculation may provide a more accurate estimate of the carbon contents of forest expected to be lost in the future (for the calculation of emission factors). For example, if a model predicts that the most probable location of future deforestation is in areas with lower carbon content (because they are largely now secondary forests), and that in the historical period mainly primary forest was lost, using historical emission factor data would over-estimate emissions in the FREL/FRL.

Guyana has included information on spatial modeling in their Forest Reference Emission Level submission to the UNFCCC. Guyana has applied spatial modeling for two purposes: 1) to stratify the forest for a more accurate carbon stock (and associated emission factor) estimation; 2) to stratify the forest (based on accessibility only) for cost-effective sampling. Guyana mentions in its FREL submission that carbon stock is not significantly different per forest type, but differs significantly per deforestation probability class resulting from their spatial modeling exercise. The deforestation probability classes in a “potential for future change” map, provide a more useful stratification for emission factor estimation. Guyana’s spatial analysis is discussed in Guyana Forestry Commission (2013).

Typically, an adjustment may be proposed when a country expects deforestation rates to increase in the future (in absence of REDD+) compared to the past due to changing pressures on the forest or changing national circumstances. Since spatial models do not simulate the quantity of future deforestation, therefore their use in calculating an adjustment for national circumstances may be limited. Both Guyana and Colombia have proposed an adjustment and have included information on spatial modeling in their FREL submission to the UNFCCC. However, for both countries their spatial modeling exercises did not play a role in calculating the adjustment.





In the context of FREL/FRL construction, the use of spatial modeling to predict the location of future deforestation may serve the following purpose:

- improve the accuracy of emission estimates from future deforestation for the FREL/FRL by providing the basis for an emission factor stratification;
- improve the accuracy of emission estimates from future deforestation for the FREL/FRL by predicting the type and/or structure of forest that will be lost in the future (approximating emission factors based on prediction rather than historical data).

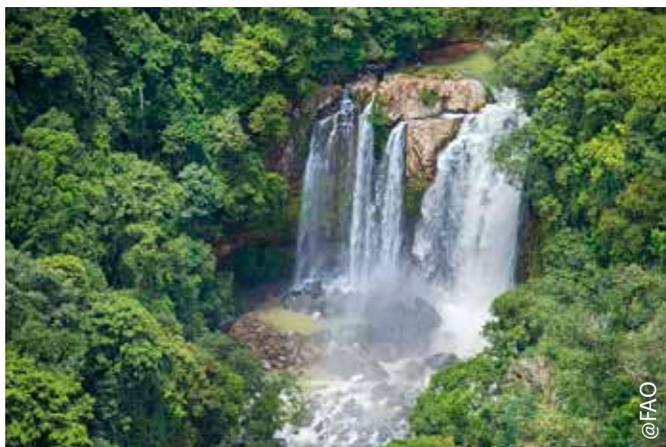
### The use of spatial models in the broader REDD+ context

As the previous section explains, the use of spatial modeling in FREL/FRL construction may be somewhat limited, but it can fulfil other purposes in the broader REDD+ context. Colombia specifies in its FREL submission to the UNFCCC that spatial modeling is a complementary and independent tool to the quantification of activity data and emission factors

(Colombia UNFCCC submission 2014). As such, the modeling currently doesn't influence the FREL calculation, rather the results of the spatial simulation are useful in strategy formulation and identifying potential area for REDD+ implementation. Additionally, Colombia mentions that the deforestation risk map could become an important tool to propose transparent benefit sharing schemes.

The use of spatial modeling to predict the location of future deforestation may serve the following (mostly domestic planning) purposes:

- inform policy making and the national REDD+ strategy;
- provide information on where the greatest deforestation pressures may be;
- help choose the location of REDD+ activities;
- help in the design of monitoring efforts and additional (intensified) data collection in anticipated deforestation hotspots.



## Limitations of spatial modeling

The type of spatial modeling described in this note relies on data describing land change patterns and often has a limited ability to evaluate conditions not observed in the past (Brown et al, 2013). The models assume that the input variable maps have a relationship with past land change and this relationship will continue in the future. This assumption relies on the user to select appropriate variables as inputs. If a variable with strong predictive power (e.g. accessibility) is omitted from the model, this can limit the model's accuracy.

Additionally, some variables may be highly dynamic, and can significantly change the forest loss probability, e.g. a new road will change the situation instantly, as well as a new mining concession or significant population migration to new locations. A comparison of different modeling platforms is given by Mas et al (2007).

The user should be aware of the mechanics of the model, including the different assumptions and approaches of the model, to avoid using the model as a black box lacking any understanding on how the final product

was created and whether the underlying assumptions are correct. A simple modeling approach assists the user in determining how the relationships between land cover maps and driver variables are extrapolated to determine the future forest loss probability.

## Validation and sensitivity analysis

Model evaluation can be implemented to test its performance; this may include validation and sensitivity analysis of the model outputs (Brown et al, 2013). Validation compares the predicted location of change with the real location of change. Validation of a forwarding looking land change model is inherently a difficult task because we have no data for the future. Validation can therefore be performed by splitting historical data into a time interval that generates the model (calibration) and time interval used to compare the predicted change with the observed change (validation) (Mas et al 2007, Pontius et al 2004). A sensitivity analysis gives an indication of how much the model results may change with different assumptions (changing the variable maps which are the main model inputs in location modeling).

Scale should be considered in model validation where the model performance (goodness of fit) is likely much lower at high resolution i.e. when predicting change locations at the level of small pixels.

## Recommendations

If a country wishes to use spatial modeling in the context of REDD+ it is useful to first understand and decide what purpose the country wants it to serve.



In FREL/FRL calculation, spatial modeling may influence emission factor estimation by considering forest locations likely to be deforested in the future and their associated carbon contents. In some cases this may provide a more accurate emission estimate than using historical data. In the FREL/FRL submissions that have been made so far by countries to the UNFCCC, there are no examples where spatial (location) modeling is used to calculate or propose adjustments to historical deforestation rates for national circumstances.

In the broader REDD+ context, spatial modeling may be useful for various purposes, including prioritizing locations for the implementation of REDD+ policies and measures and informing the REDD+ National Strategy and/or Action Plan.

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