VT0007

JNR RISK MAPPING TOOL

DRAFT

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ACKNOWLEDGMENTS

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1 OBJECTIVE

The *JNR Risk Mapping Tool* is a "benchmark" methodology that provides a standardized approach for developing deforestation and forest degradation risk maps for users of the *JNR Allocation Tool in the context of Verra's Jurisdictional and Nested REDD+ (JNR) Requirements.*

The tool allows the creation of categorical and spatially static maps whose categories represent different levels of risk of deforestation or forest degradation in the validity period of the Forest Reference Emissions Level (FREL) and throughout the jurisdictional geographical boundaries.

In the *JNR Allocation Tool*, the level of risk determines how the jurisdictional FREL is spatially distributed to nested lower-level jurisdictional programs and projects.

2 APPLICABILITY

The *JNR Risk Mapping Tool* may be used by higher-level jurisdictions that want to allocate their FREL to projects or lower-level jurisdictions. This tool shall be used together with the *JNR Allocation Tool.* The tool is applicable to unplanned deforestation and unplanned forest degradation.

Users of the *JNR Allocation Tool* may create risk maps using the approach that they consider most appropriate. However, where risk maps are created using an alternative approach than the *JNR Risk Mapping Tool*, the following conditions apply:

1) The alternative approach must be assessed during validation by a VVB against the requirements set out in this document and any other relevant VCS Program requirements following applicable VCS procedures.
2) The risk map created with the alternative approach must include the "insignificant risk" class as determined with the methods described in Section 3.4(2).
3) The risk map created with the alternative approach must be of similar or better quality than the best risk map produced with this *JNR Risk Mapping Tool*.
4) The comparison of the quality of risk maps shall be carried out using the methods described in Section 4.

3 TOOL DESCRIPTION

3.1 Criteria Considered in the Development of the Approach

The goal of the *JNR Risk Mapping Tool* is to produce risk maps to carry out risk-based allocations of jurisdictional FRELs to nested lower-level jurisdictional programs and projects using the *JNR Allocation*

Tool. Considering its scope of application, the approach was developed according to the following criteria:

1) The approach should minimize opportunities for biased FREL allocations.

2) The approach must be effective in detecting areas where the risk of deforestation and forest degradation is insignificant and therefore negligible.

3) The data requirements of the approach should be as minimal as possible for the tool to be applicable in the widest possible country contexts.

4) The technical approach of the approach must be as simple as possible to minimize the risk of errors in its application and the verification of its results, while remaining effective in discriminating areas of different risk levels.

3.2 Data Requirements

The tool requires the following data:

1) A wall-to-wall map of historical deforestation covering the entire jurisdictional area whose FREL is to be allocated to nested lower-level jurisdictional programs and projects. The map shall comply with the criteria set out in Section 3.3 and include data referring to at least two periods of similar duration (2-3 years) that together represent the total deforestation that occurred during the historical reference period (4-6 years) of the jurisdictional FREL.

2) Where forest degradation is included in the FREL, a map of historical forest degradation meeting the same requirements of the deforestation map is required.

3) A wall-to-wall Forest Cover Benchmark Map (FCBM) covering the entire jurisdictional area. The FCBM shall represent areas of land that meet the jurisdictional definition of "forest" as set out in the VCS Program document *Program Definitions* on either the start, middle, or end date of the FREL historical reference period, so that additional FCBMs can be built, as needed, by combining the known FCBM with the map of historical deforestation.

4) Where projects have been credited for avoided deforestation or avoided forest degradation in past periods and the exact location of the areas that generated carbon credits is known, such areas should be disclosed in a map, separately for areas of avoided deforestation and areas of avoided forest degradation.

The *JNR Risk Mapping Tool* does not require any other data, thus complying with criterion in Section 3.1(3). Box 1 discusses some of the reasons that have been considered to keep the data requirements of the tool to a minimum.

Box 1. Considerations on data requirements for risk mapping.

Several deforestation and degradation risk-modelling approaches and tools exist, and have been used, to create risk maps and spatially explicit models in the context of setting the baseline of stand-alone REDD+ projects. Most of these approaches are based on the selection of "factor maps" representing landscape features such as roads, navigable water streams, recently deforested areas, settlements, etc., whose proximity to forested areas are hypothesized to be factors promoting deforestation and forest degradation. The hypothesis is tested by creating distance maps from the spatial characteristics represented in the factor maps and evaluating whether historical deforestation and forest degradation have a non-random and therefore predictable behavior at different distances.

Factor maps can also represent discrete landscape categories, such as slope classes, management categories, soil fertility classes, climate categories, etc., that are supposed to make a particular place more or less likely to be deforested or degraded.

The distance variables and landscape categories for which there is a statistically non-random relationship to deforestation and forest degradation can be used to predict the risk of deforestation and forest degradation in the future. If the process of selecting factor maps, constructing distance and categorical maps, and modelling the risk is unbiased and statistically sound, this type of approaches can be used to create good-quality deforestation and forest degradation risk maps.

Finding good-quality factors maps, however, can be challenging in REDD+ countries. National-scale maps are often outdated, too coarsely scaled, and difficult to obtain from official sources in the digital formats needed to build spatial models. In regions where deforestation and forest degradation are advancing very fast there is often an almost simultaneous development of roads, settlements, and other types of infrastructure that is not visible in national scale maps. This implies that even recently updated national maps are likely to quickly become inaccurate and outdated, particularly in areas where the land use is changing very rapidly.

If factor maps are too coarse and out of date, particularly in hotspot areas of deforestation and forest degradation, risk models developed with these maps will be poorly calibrated and the resulting risk maps will not be of good quality. To address this problem, complementing existing factor maps by digitalizing the features that are not represented in them is an option, but carrying out this work meticulously in the entire jurisdictional area can be costly and time-consuming. If the factor maps are updated and improved only in certain regions of interest, such as project areas and hotspots areas of deforestation and forest degradation, the calibration of the risk model will be inherently biased.

To avoid these problems, and to be consistent with the criteria considered in the design of the *JNR Risk Mapping Tool* (see Section 3.1), the tool avoids working with factor maps. This, however, does not imply that risk modelling approaches that use good quality factor maps cannot produce higher quality deforestation and forest degradation risk maps than the *JNR Risk Mapping Tool*, and this is why the option is provided for the use of such approaches where they meet minimum criteria.

3.3   Considerations on Data Sources

1) Where activity data used in the construction of the jurisdictional FREL have been estimated through pixel counts, the map used to count the pixels should be used for risk mapping, taking into consideration the following:
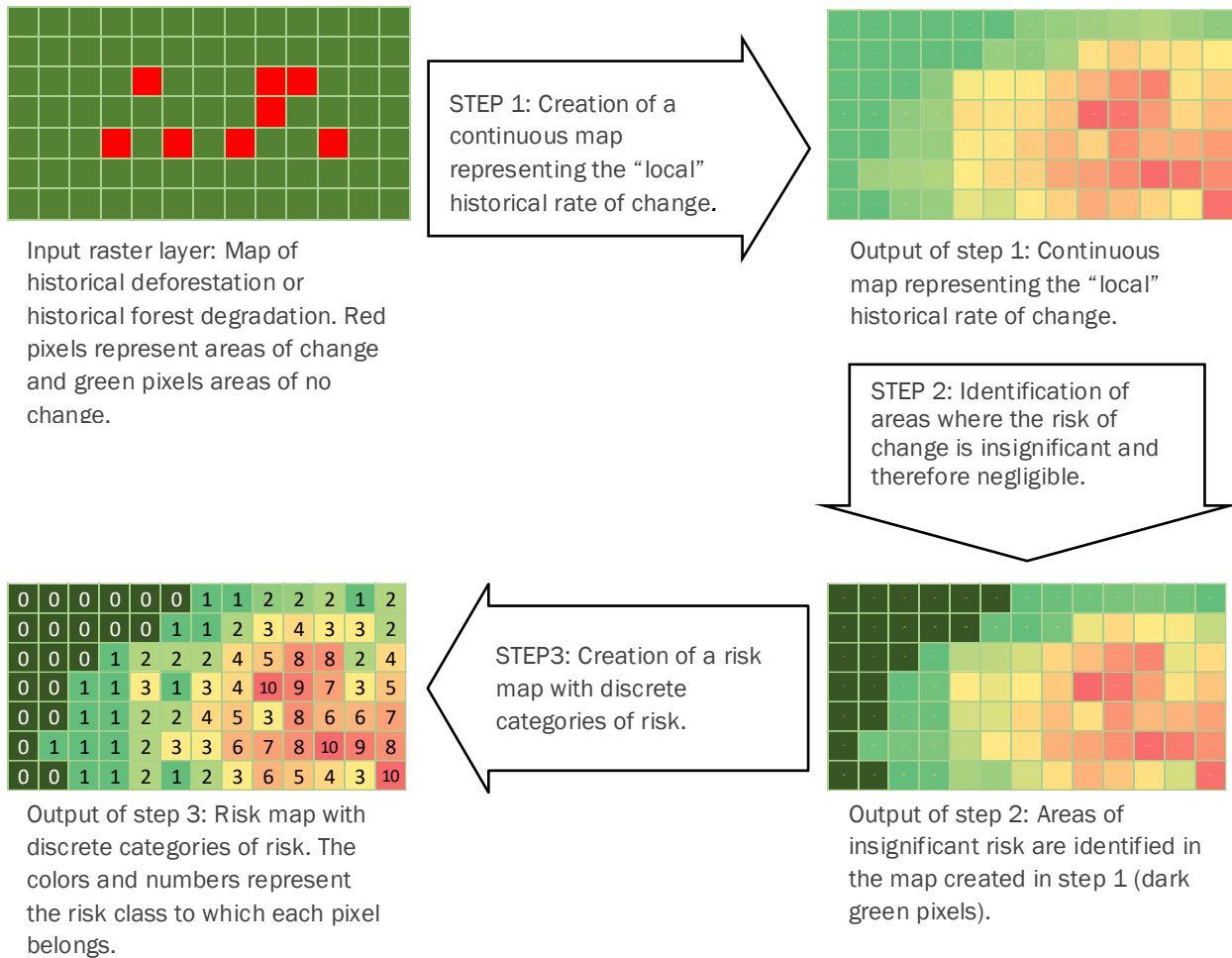
a) Since activity data estimated through pixel counts must be corrected for bias, the values of deforested or degraded areas extracted from historical maps may not be consistent with the estimates of bias-corrected activity data. Where multiple sources of maps of historical deforestation and forest degradation are available, those with the smallest difference between the map data and the bias-corrected activity data estimates should be used for risk mapping.

b) Where the difference between map data and bias-corrected activity data estimates is more than ±20% of the bias-corrected activity data estimates, alternative national and international sources of spatially explicit deforestation and forest degradation data should be evaluated and, if they have a smaller difference between map data and bias-corrected activity data estimates, they should be used for risk mapping.

2) Where activity data have been estimated through stratified sampling, any national or international source of spatially explicit deforestation and forest degradation data deemed appropriate for risk mapping can be used. The sources whose maps have the smallest difference between map data and activity data estimates through stratified sampling should be used.

3) The spatial resolution of the maps shall not be coarser than the minimum area threshold of the definition of "forest".[1]

4) Where the spatial resolution of the maps is smaller than the minimum area threshold of the definition of "forest" it is good practice to filter the maps to eliminate any area below the minimum area threshold of the definition of "forest".

5) Where planned deforestation or planned forest degradation are included in the jurisdictional FREL, the areas corresponding to these activities should not be excluded in the calibration and validation of the risk maps.

6) Where planned deforestation or planned forest degradation are included in the jurisdictional FREL, the areas corresponding to these activities should not be excluded in the calibration and validation of the risk maps.

3.4   Risk Modelling Approach

The risk modelling approach builds on the hypothesis that the "local" deforestation and forest degradation rates of the recent past (i.e., the "FREL historical reference period") are, in most cases, a good predictor of the risk of deforestation and forest degradation in the immediate future (i.e., the "FREL validity period").

Based on this hypothesis, the risk map is created in three basic steps, as illustrated in Figure 1.

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[1]   Spatial resolutions below 60 x 60 meters are not recommended to save computer processing time.

Figure 1. Basic steps of the modelling approach used in the *JNR Risk Mapping Tool*.

Input raster layer: Map of historical deforestation or historical forest degradation. Red pixels represent areas of change and green pixels areas of no change.

STEP 1: Creation of a continuous map representing the "local" historical rate of change.

Output of step 1: Continuous map representing the "local" historical rate of change.

STEP 2: Identification of areas where the risk of change is insignificant and therefore negligible.

STEP3: Creation of a risk map with discrete categories of risk.

Output of step 3: Risk map with discrete categories of risk. The colors and numbers represent the risk class to which each pixel belongs.

Output of step 2: Areas of insignificant risk are identified in the map created in step 1 (dark green pixels).

STEP 1: Creation of a continuous map representing the "local" historical rate of change.

In the context of the *JNR Risk Mapping Tool*, "local" is a square "window" of X x X pixels that moves throughout the historical deforestation or forest degradation map and that calculates the historical rate of change corresponding to the area delimited by the window. The calculated rate is written in the central pixel of the moving window in the output raster layer. The rate of change is calculated with the following equation:

$$r = \left(\frac{A_2}{A_1}\right)^{\frac{1}{T}} - 1$$

Eq. 1

Where:

r Deforestation or forest degradation rate; %/year.

A_1 Area of forest at time t_1 (or area of undegraded forest at time t_1); hectares.

A_2 Area of forest at time t_2 (or area of undegraded forest at time t_2); hectares.

T Number of years elapsed between t_1 and t_2; years.

The moving windows creates a smooth, continuous, output raster layer in which each pixel contains information on the "local" (X x X pixels) activity data rate of the recent past as a predictor of the risk (or probability) of future change (see Figure 2).

The output raster layer will be different depending on the number of pixels included in the moving window. As the optimal size of the window cannot be known in advance, it is necessary to create various risk maps using windows of different sizes and to compare the risk maps, using the methods described in Section 4, to select the best risk map.

At least 25 risk maps should be created using windows of different sizes. The optimal window size is usually between 600 x 600 m and 30,000 x 30,000 m. However, depending on the predominant spatio-temporal configuration of deforestation or forest degradation in the jurisdiction, the optimal window size may be outside this range.

STEP 2: Identification of areas of insignificant risk.

To avoid allocating baseline emissions to areas where the risk of deforestation or forest degradation is insignificant, the following analysis must be performed:

1) Determine the number of hectares deforested or degraded during the historical reference period as a function of the distance from the edge of the forest that existed <u>at the beginning of the historical reference period of the FREL</u>. Measure the distance from the edge of the forest to the inside of the forest. In most cases this analysis will result in a curve that looks like the one presented in Figure 3.

2) Determine the distance at which 99% of the deforestation or forest degradation occurred during the historical reference period of the FREL.

3) Create a buffer zone around the edge of the non-forest land area that exists <u>at the beginning of the FREL validity period</u> using the calculated distance. If a FCBM map for the date corresponding to the beginning of the FREL validity period is unavailable, the buffer zone can be created around the edge of the non-forest area that existed at the end of the historical reference period of the FREL.

4) All areas of forest that are not included in the buffer zone are assumed to be areas where the risk of deforestation or forest degradation is insignificant and therefore negligible; these areas must be included in the "0" risk class of the *JNR Allocation Tool*. The *JNR Allocation Tool* will not allocate any baseline emissions to the "0" risk class.

Projects that generated Verified Carbon Units (VCUs) for avoided deforestation or avoided forest degradation in past baseline periods should not be credited again for the same emission reductions in the current and any future FREL validity period. To avoid this to happen, the following applies:

1) Areas credited for avoided deforestation in past periods should be included in the "0" risk class of both, the deforestation and the forest degradation risk map, not because they are assumed to be under negligible threat, but because they were already credited.

2) Areas credited for avoided forest degradation in past periods should be included in the "0" risk class of the forest degradation risk map only. In the *JNR Allocation Tool* these areas should be included in a separate forest stratum, with a carbon stock that is equal to the difference between the actual carbon stock and the already per-hectare credited emission reductions for avoided forest degradation.

Where spatially explicit information on the exact areas that generated carbon credits in past periods is unavailable so that these areas cannot be included in the risk class "0", the number of verified emission reductions (VCUs and buffer credits) must be provided in the sheet DATA.2 of the JNR Allocation Tool. The JNR Allocation Tool will use these data to cap the allocation to nested projects and jurisdictional programs so that the allocated portion of the FREL does not exceed the remaining mitigation potential that exists within each project and jurisdictional program area (see JNR Allocation Tool Guidance Document).

STEP 3: Creation of a risk map with discrete categories of risk.

Considering that the outcome of STEP 1 is a smooth, continuous, raster layer in which the pixel values have decimal values, and that the *JNR Allocation Tool* requires a map with up to 31 discrete "risk classes" (including the "0"-risk class discussed above) with pixel values ranging from 0 to 30, the area not covered by the "0" risk class, as determined with STEP 2, must be sliced in up to 30 discrete categories (called "risk classes" in the *JNR Allocation Tool*) to create a categorical risk map to which portions of the FREL will be allocated proportionally to the level of historical emissions estimated for each risk class.

Spatial modelling tools offer different types of slicing algorithms and it is not possible to know in advance what slicing algorithm will produce the best risk map. For this reason, it is required to test at least three slicing algorithms, such as "Equal Area", "Equal Interval" and "Natural Breaks", noting the following:

1) The number of slicing algorithms multiplies the number of risk maps to be evaluated (e.g., if 30 windows and 3 algorithms are tested, 90 risk maps will have to be evaluated and compared).

2) When "Equal Area" is used, the classes with a risk > 0 are expected to have approximately the same surface area in the risk map. However, if certain values in the layer created in STEP 1 are predominant, it is possible that certain risk classes will include a larger-than-expected surface area and that the total number of risk classes will be lower than expected.

3) When "Equal Interval" is used, some risk classes will predominate in the risk map while other classes will be present only in small areas.

4) When "Natural Breaks" is used, the data should be normalized before running the slicing algorithm.

Figure 2. "Moving window" approach.
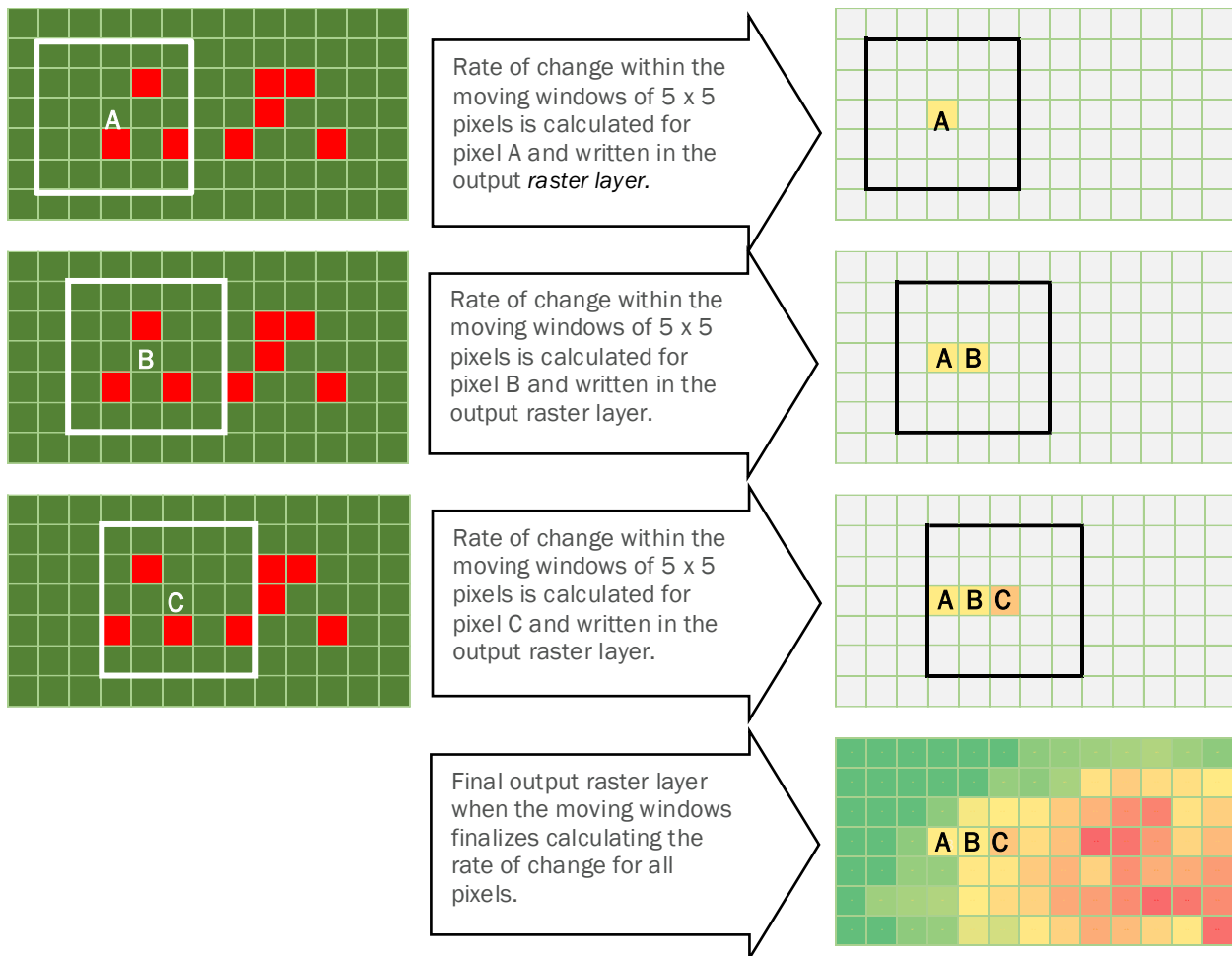
In Figure 2, the input raster layer is shown three times on the left and the output raster layer that the moving window creates is shown four times on the right. Green cells in the input raster layer represent pixels classified as "forest" and red cells pixels classified as "deforestation". The square of 5 x 5 pixels with A, B, C in the center represents the "moving window". The moving window with pixel "A" in its center calculates the rate of change within the area of the window using Eq. 1 and writes the calculated rate in pixel A of the output raster layer. In the next iteration, the moving window is displaced one pixel to the right and repeats the same calculation for pixel B. Once finished with pixel B, the window is displaced once again one pixel to the right to do another iteration, this time for pixel C, and so on for all pixels of the input raster layer. In the example illustrated in Figure 2, pixels A and B in the output raster layer will have the same estimated rate, because in both cases there are 3 deforested pixels in the input raster layer within the area of the moving window. Pixel C in the output raster layer will have a higher estimated rate because there are 4 deforested pixels in the input raster layer within the area of the moving window. At the end of the process, the completed output raster layer looks like as shown on the bottom-right of Figure 2. The colors of the pixels in the final output raster layer represent different values of the "local" rate of change.

Figure 3. Determination of areas where the risk of deforestation or forest degradation is insignificant and therefore negligible.
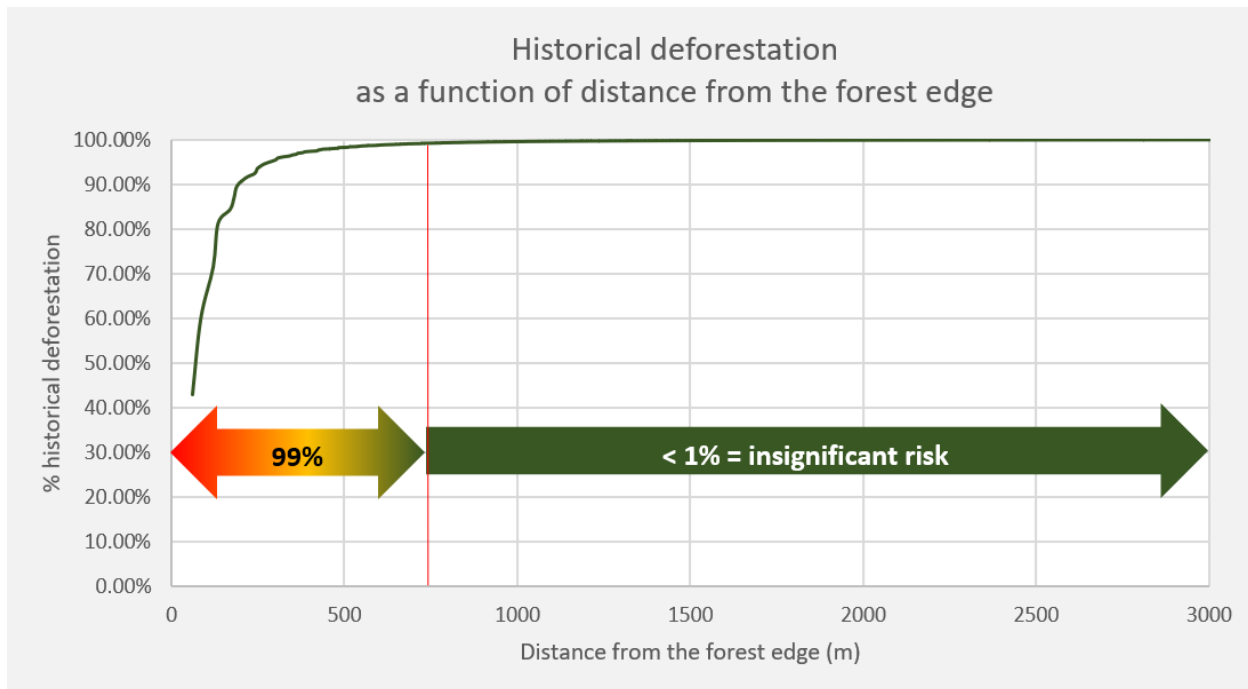
4 RISK MAP COMPARISON AND SELECTION OF THE BEST RISK MAP

4.1   Principle

To avoid subjective choices in the determination of the size of the moving window in STEP 1 and of the slicing algorithm in STEP 3, several risk maps must be created using moving windows of different sizes and slicing algorithms of different type, such as "equal area", "equal interval", and "natural breaks". The resulting maps must be evaluated and compared using a standardized approach to select the window size and the slicing algorithm that produces the best risk map.

If the user of the *JNR Allocation Tool* intends to apply an alternative approach to create risk maps it will be necessary to compare the risk maps created with the alternative approach with the best risk map created with the *JNR Risk Mapping Tool*.

4.2   Requirements for Risk Map Comparison

For risk maps to be comparable the following requirements must be met:

1) The maps of historical deforestation and forest degradation used to calibrate the different risk maps must be the same.

2) The reference years used to calibrate and validate the risk maps must be the same.

3) The spatial resolution of the risk maps must be the same.

4) Areas of planned deforestation and planned forest degradation shall not be excluded from the calibration and validation data sets.

5) All risk maps must include the "0" risk class as determined following the method described in Section 3.4, STEP 2.

6) The risk maps must be categorical and have the same number of risk classes.

4.3   Evaluation Procedure

The evaluation of risk maps is based on calibrating and validating each of them with the same set of deforestation or forest degradation data. To this end, the historical reference period of the FREL shall be divided in a "calibration period" of 2-3 years and in a more recent "validation period" of similar duration.

The risk maps to be evaluated and compared shall be created with data from the calibration period only.

A grid with a mesh distance of up to a maximum of 10 x 10 km is used to assess the quality of the risk maps. The mesh distance depends on the total area of forest in the jurisdiction and shall be determined so that at least 1,000 grids containing forests[2] at the beginning of the validation period will fall within the jurisdictional area.

The evaluation procedure is as follows:

1) Grids that do not contain any forest at the beginning of the validation period shall be excluded from the evaluation.

2) Using Equation 1, calculate for each risk class the historical deforestation rate or the historical forest degradation rate corresponding to the calibration years.

3) Using the calculated rates and taking into consideration the area of forest that exists in each risk class within each grid at the end of the calibration period, calculate a prediction of the number

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[2]   Grids that are only partially covered by forests at the beginning of the historical reference period of the FREL should not be excluded from the evaluation procedure. The tool uses a weighting approach to account for the fact that some grids contain more forests than others (see Eq. 2 in (6)).

of hectares that would be expected to be deforested or degraded in each grid during the validation period.

4) For each grid, determine the number of hectares of actual deforestation or forest degradation that happened in the validation period. The scatter plot of observed versus predicted deforestation or degradation should look like shown in Figure 4.

5) For each grid, calculate the difference between "observed" and "predicted" deforestation or forest degradation.

6) Calculate the weight of each grid based on the number of hectares of forest that existed within each grid at the end of the calibration period using the following equation:

$$Wg = \frac{AFg}{AFj} \qquad\qquad \text{Eq. 2}$$

Where:

Wg Weight of grid g; dimensionless

AFg Area of forest in grid g at the end of the calibration period; hectares

AFj Area of forest in the jurisdictional FREL boundary at the end of the calibration period; hectares

7) Calculate the weighted Root Mean Squared Error (wRMSE) of the differences between "observed" and "predicted" deforestation or forest degradation using the following equation:

$$wRMSE = \sqrt{\frac{\Sigma_g^G (O_g - P_g)^2 * W_g}{\Sigma_g^G W_g}} \qquad\qquad \text{Eq. 3}$$

Where:

$wRMSE$ Weighted Root Mean Squared Error; hectares.

Og Observed deforestation or degradation in grid g during the validation period: hectares.

Pg Predicted deforestation or degradation in grid g for the validation period: hectares.

Wg Weight of grid g; dimensionless.

G Total number of grids with at least one pixel of "forest" in them at the end of the calibration period; dimensionless.

8) The risk map with the smallest wRMSE value shall be considered the best risk map.

Figure 4. Example of a scatter plot of observed versus predicted deforestation.

Observed versus predicted deforestation (ha) in 10 x 10 km grids
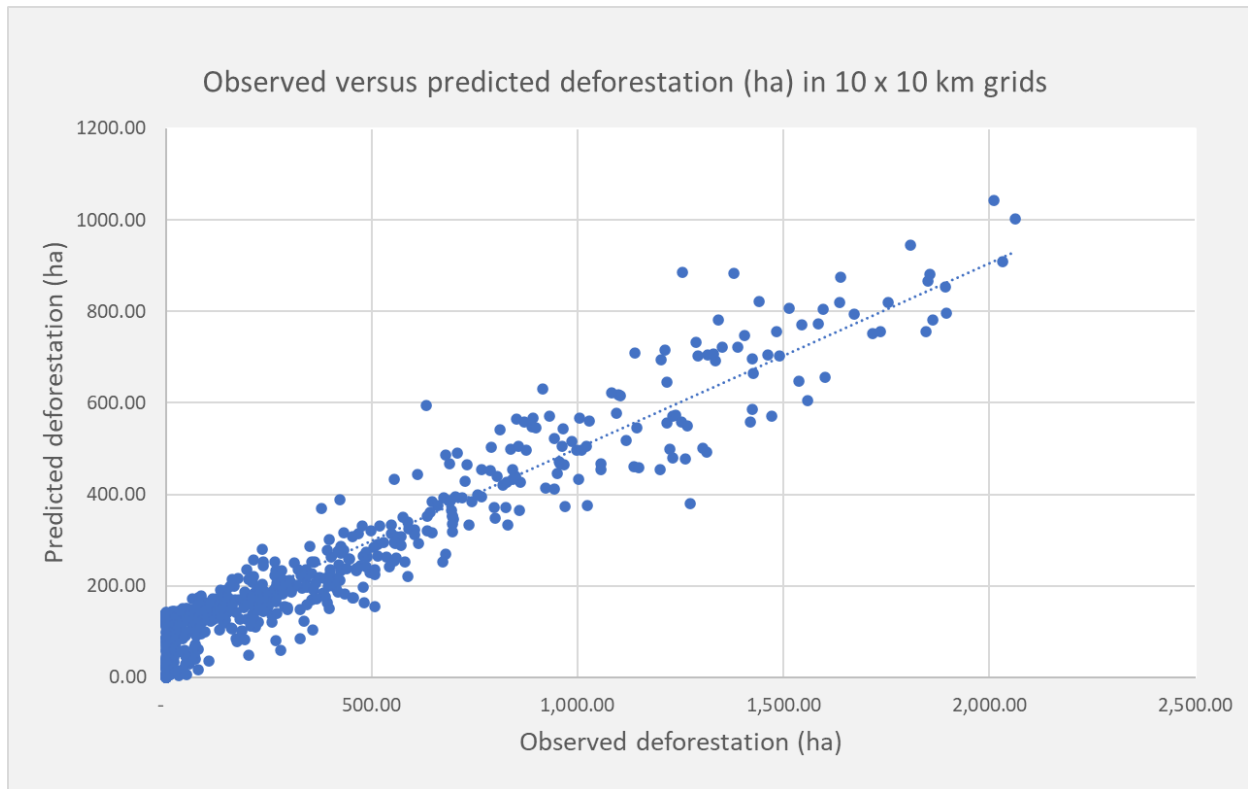
4.4   Construction of the Final Risk Map

If the risk map with the smallest wRMSE has been constructed with an alternative approach, the final risk map to be used for calculating the FREL allocation to nested lower-level jurisdictional programs and projects using the *JNR Allocation Tool* shall be constructed with the alternative approach.

If the risk map with the smallest wRMSE has been constructed with the *JNR Risk Mapping Tool*, the corresponding window size and slicing algorithm shall be used to create the final risk map that will be used for calculating the FREL allocation to nested lower-level jurisdictional programs and projects using the *JNR Allocation Tool*.

In all cases, the final risk map must be calibrated with the deforestation or forest degradation of the entire historical reference period of the FREL, i.e., with the combined data of the "calibration" and "validation" period.