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BIOME-SPECIFIC FOREST DEFINITIONS

Technical paper

Report[1] to the UNFCCC secretariat
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Acronyms and other abbreviations

ARD	afforestation, reforestation and deforestation
AOSIS	Alliance of Small Island States
COP	Conference of the Parties (to the United Nations Framework Convention on Climate Change)
EFTA	European Free Trade Association
EU	European Union
FAO	Food and Agriculture Organization (of the United Nations)
FRA	Forest Resources Assessment (by FAO)
GEZ	global ecological zone/zoning
GIS	geographical information system
IPCC	Intergovernmental Panel on Climate Change
LULUCF	land use, land-use change and forestry
SBSTA	Subsidiary Body for Scientific and Technological Advice
TBFRA	Temperate and Boreal Forest Resources Assessment (UN-ECE and FAO)
UN-ECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
WWF	World Wide Fund for Nature

I. SUMMARY

1. Parties to the UNFCCC have agreed on a forest definition for the purposes of Article 3.3. and 3.4 of the Kyoto Protocol, to be applied for the first commitment period. At the same time, they requested the SBSTA to investigate the possible application of "biome-specific forest definitions" for the second and subsequent commitment periods. This paper investigates the potential implications of such a change in definition.

2. First, the possible interpretations of "biome" are considered. It is shown that the meaning of "biome" in the given context is less than clear, and some plausible scenarios for the adoption of a reasonably consistent and meaningful biome classification system are outlined. It is argued that the adoption of a sufficiently detailed and ecologically meaningful biome classification system will require considerable effort, even if it is based on an existing classification system. Of the existing global biome classifications, the GEZ system, developed for the purposes of the Forest Resources Assessment 2000 programme of the FAO, is presented as the most practical choice.

3. It is argued that whatever zoning system is to be adopted, the forest definition in each biome is likely to follow the current structure based on minimum tree height, minimum crown density (or similar measure) and minimum area, but with different minimum values. An analysis of the impact of each of these parameters on the corresponding forest area and on the feasibility of ARD activities indicated that the forest definition can have a significant impact on the area qualifying as forest, especially near the natural boundaries of forest distribution, and in heavily impacted (degradation, fragmentation) communities.

4. There is no strong indication that a change in the way forests are defined in any ecological zone would lead to appreciable benefits either in terms of consistency of carbon estimates (agreement with the real values) or in terms of environmental benefits. The adoption of biome-specific forest definitions, if biome boundaries are not identical with national boundaries, is likely to make carbon accounting more difficult and/or less accurate, and is likely to lead to inconsistencies among forest carbon estimates of different biomes within countries (since different definitions are likely to result in different error structures).

5. The analysis of the implications of changing from one forest definition to another (be it biome-specific or otherwise) identified areas of concern. A change in forest definition between commitment periods will require double accounting (at least for the time of the changeover). In addition, it will inevitably create apparent changes in the amount of forest indicated, even if there is no actual change in the amount of woody vegetation. These apparent gains and/or losses of forest area will have to be differentiated from actual changes in woody vegetation. Separating accounted changes owing to real processes and those resulting from the definition change may pose considerable methodological problems. A change in forest definition may also lead to paradoxical situations, may generate perverse incentives and may provide opportunities for abuses of the system.

II. INTRODUCTION

A. Background

6. Under Article 3.1 of the Kyoto Protocol, Annex I Parties have agreed to reduce their emissions of greenhouse gases between 2008 and 2012. The Kyoto Protocol makes provision for Annex I Parties to take into account afforestation, reforestation and deforestation (ARD) activities (under Article 3.3) and other agreed land use, land-use change, and forestry (LULUCF) activities (under Article 3.4) in meeting their commitments under Article 3. The use of LULUCF activities is also acknowledged under Article 6

and incorporated under decision 17/CP7 relating to Article 12, where only eligible projects are limited to afforestation and reforestation (see also decision 11/CP.7).

7. The definitions, modalities, rules and guidelines relating to LULUCF activities under Articles 3, 6 and 12 of the Kyoto Protocol were considered by the resumed sixth session of the Conference of the Parties. The resulting decision (11/CP.7) recommends that the first COP serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP1) adopts, for application in the first commitment period, the definitions for "forest" and for ARD activities.[3]

8. The primary function of the forest definition in this context is the identification of areas affected by ARD activities. Thus, such activities are considered only on areas of land which are converted from forest to non-forest or non-forest to forest (as specified by the forest definition). This affects the application of Article 3.3 and has implications for Articles 6 and 12 (e.g. eligibility for CDM activities). In addition, forest management activities, allowed under Article 3.4, can be carried out only on forest land.

9. The decision mentioned above, however, leaves the door open for a different forest definition to be used in the future by requesting the SBSTA to investigate the possible application of biome-specific forest definitions for the second and subsequent commitment periods.

10. This paper investigates some methodological issues relating to the possible implementation of biome-specific forest definitions.

B. Methodology and structure of the report

11. The study is based on an analysis of the text of the UNFCCC, the Kyoto Protocol and relevant decisions of the COP. It relies on the reports and guidelines issued by the IPCC, and takes into account relevant international conventions, agreements and processes, especially the relevant efforts of FAO. It draws heavily on the technical literature and expert consultations.

12. The report assumes the following logical sequence in arriving at "biome-specific forest definitions":

(a) The land surface of the Earth is first divided into a finite number of biomes in such a way that any point can be assigned to one biome;

(b) For all of the biomes identified in step (a), there has to be a definition of "forest";

(c) For at least one of the biomes, the for definition of forest is different from that agreed upon by Parties for the first commitment period.

13. The relevant sources were reviewed for the above steps. As there are virtually limitless possibilities both for defining/delineating "biomes" and for defining "forest", the discussion is limited to the most plausible scenarios.

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[3] "Forest" is a minimum area of land of 0.05-1.0 hectares with tree crown cover (or equivalent stocking level) of more than 10-30 per cent of trees with the potential to reach a minimum height of 2-5 metres at maturity *in situital*. A forest may consist either of closed forest formations where trees of various heights and undergrowth cover a high proportion of the ground, or of open forest. Young natural stands and all plantations which have yet to reach a crown density of 10-30 per cent or tree height of 2-5 metres are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention such as harvesting, or of natural causes, but which are expected to revert to forest.

Each Party included in Annex I shall […] select a single minimum tree crown cover value between 10 and 30 per cent, a single minimum land area value between 0.05 and 1 hectare and a single minimum tree height value between 2 and 5 metres. The selection made by a Party shall be fixed for the duration of the first commitment period.

14. Section 2 reviews the text of the Convention, the Kyoto protocol and available IPCC documents, as well as other relevant sources for guidance on the appropriate interpretation of the expressions “biome” and “biome-specific”. Addressing step (a) above, plausible scenarios for the specification of biomes are outlined, highlighting the most important theoretical and practical issues associated with each.

15. Section 3 addresses step (b) above by considering scenarios for the definition of “forest” in the various biomes. It investigates the potential benefits and disadvantages of the different choices.

16. Section 4 addresses step (c) above by exploring the potential implications of switching from the current forest definition (adopted for the first commitment period) to “biome-specific” definitions for the subsequent commitment periods.

17. Section 5 synthesizes the main findings of the report.

III. BIOME MAPPING

18. To analyze the implications of “biome-specific” definitions, the plausible options for delineating “biomes” have to be explored. In this section, relevant sources of information are reviewed in search guidance on the possible definition(s) of “biome” in the given context. Options are presented for the development/adoption of a biome classification system, and the implications of each.

A. Review of sources

1. Generic reference sources

19. This section examines the definitions offered by major reference sources. First, some definitions for “biome” are reviewed.

20. The Oxford English Dictionary (1989) defines biome as "A biotic community of plants and animals, spec. such a community in a prehistoric period", suggesting the importance of the potential vegetation type (by referring to a "prehistoric period"). The Merriam-Webster Collegiate Dictionary (2001) provides some examples to illustrate the level of classification it assigns to the biome concept.[4]

21. The Encyclopaedia Britannica (1995) emphasizes that biomes are large units. However, by introducing the concept of "biome type" (a grouping of biomes), it makes clear that biomes are not the highest level of classification of life zones.[5] While it gives "temperate deciduous forests" as an example of a "biome type", the McGraw-Hill Encyclopedia of Science & Technology (1992) uses the same forest type as an example of "biome",[6] demonstrating that the level of classification assigned to the biome concept is somewhat arbitrary.

22. All the above sources also offer synonyms for the term “biome”, which happens to be just one of several words and expressions denoting similar concepts. These include: *formation, major life form, major life zone, major community (type).* Although not mentioned above, *ecoregion* and *ecofloristic zone*

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[4] **biome** a major ecological community type (as tropical rain forest, grassland, or desert).

[5] **biome**, also called major life zone, the largest geographic biotic unit, a major community of plants and animals with similar life forms and environmental conditions. It includes various communities and developmental stages of communities and is named for the dominant type of vegetation, such as grassland or coniferous forest. Several similar biomes constitute a biome type – for example, the temperate deciduous forest biome type includes the deciduous forest biomes of Asia, Europe and North America. “Major life zone” is the European phrase for the North American biome concept.

[6] **biome** A major community of plants and animals having similar life forms or morphological features and existing under similar environmental conditions. The biome, which may be used at the scale of entire continents, is the largest useful biological community unit. In Europe, the equivalent term for biome is major life zone, and throughout the world, if only plants are considered, the term used is formation. […] Each biome may contain several different types of ecosystems. […] Terrestrial biomes are usually identified by the dominant plant component, such as the temperate deciduous forest. […]

are also related terms and can be considered as synonyms. Although they may differ in their origin or area of application, they should all be treated as different interpretations of "biome". Some are rather vague,[7] while others are more specific[8] about the level of classification implied.

2. IPCC documents

23. Further to the above generic definitions, various IPCC documents provide some guidance as to how "biome" and "biome-specific" may be interpreted in the context of the Kyoto Protocol.

24. The IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) make no explicit reference to "biomes". However, there are several sections which can be interpreted as guidance for the development of biome-specific forest definitions. The following expressions, referring to the categorisation of forests, can be found in the Guidelines: *forest category*, *forest formation*, *ecosystem category*, *ecosystem type*, *vegetation cover class*. These expressions are used in the document more or less interchangeably and in a rather inconsistent fashion.

25. Specifically, three ecosystem types are described, with three to six sub-types in each. Countries are encouraged to use more detailed classification where applicable/feasible, but they are also required to report aggregate figures for the categories specified. This suggests that any detailed national classification should be compatible with the categories given. However, these categories are not well defined. For the tropics, the categories are based "mainly on the FAO system", referring to the FAO Forest Resources Assessment 1990 (FAO, 1993), which has since been revised (FAO, 2001). No clear reference is given for the other "ecosystem types", which makes application of the FRA problematic. (For example, it is unclear how the vast amount of temperate mixed forest can be classified within the "coniferous" or "broadleaf" category.)

26. The IPCC Special Report on Land Use, Land-use Change and Forestry (IPCC, 2000) (SR- LULUCF) provides a detailed analysis of the main implications of some definitional scenarios for "forest" and related terms. One of these (the "biome scenario") assumes that different definitions will be developed for different biomes. However, the report stops short of discussing what those biomes might be, or how to delineate them.

27. The IPCC Special Report on Regional Impacts of Climate Change (IPCC, 1998) includes many references to different vegetation classification systems. In its glossary, it includes the following definition:

biome: A grouping of similar plant and animal communities into broad landscape units that occur under similar environmental conditions.

28. It does not specify one particular classification system as preferable to others. It presents an ecoregional map of North America (figure 8-3), and one for Latin America (figure 6-4), but the two use different classification systems, and the ecoregion boundaries do not match at the border of the two maps, suggesting that the two systems are not fully compatible.

29. The IPCC Third Assessment Report (IPCC, 2001) makes reference to some of the African ecoregions as "biomes" (such as the Succulent Karoo biome in South Africa), suggesting a very detailed classification system.

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7 **formation** *Ecol.* A community formed by groups of plants which have adapted themselves to similar climatic conditions. Oxford English Dictionary (1989).

8 **formation** the largest unit in an ecological community comprising two or more associations and their precursors <grassland *formation*>. Merriam-Webster Collegiate Dictionary (2001).

30. While it is clear that not all uses of the word “biome” can be considered as an endorsement of a certain kind of classification system, it must be pointed out that a multitude of interpretations are available and have been used within the climate change context.

3. UNFCCC documents

31. The text of the Convention and its Kyoto Protocol do not contain the word “biome”, neither do they provide any guidance as to possible interpretation of the concept.

32. Having reviewed the decisions of the COP and the recommendations of the SBSTA, few documents make explicit reference to biomes as such, and none offer clear guidance as to how the biomes should be defined/delineated, let alone what the specific forest definitions might be. Beyond the one already mentioned above (11/CP.7), the following are to be noted.

33. There are several submissions by Parties recommending the adoption of forest definitions which are specific to biome categories. Samoa (on behalf of the AOSIS group) suggested that "forest" should be defined for the following “biome categories”: tropical forests, temperate forests, boreal forests, tropical savannas, temperate grasslands, deserts and semi-deserts, tundra and wetlands.[9] Chile[10] suggested that “a single threshold of canopy cover be adopted for each relevant biome, such as tropical moist forest, tropical dry forest, boreal forest, temperate forest, planted forest and agroforestry, among others, in order to reduce bias in defining lands under Article 3.3”.

34. A common element that can be inferred from the submissions by Parties is that they recommend broad ecological categories as “biomes”, and there seems to be an agreement that forest definitions should be assigned to the different biomes internationally, rather than allowing Parties to set their own definitions. Although these submissions are not definitive, they provide indications of the intentions of some Parties who promoted the use of biome-specific forest definitions during the process of responding to the Buenos Aires Plan of Action. For example, it is interesting to note that Chile’s submission considers management categories (planted forest and agroforestry) among the biome designations.

B. Scenarios for the adoption of a biome classification system

35. The above discussion has concentrated on the concept of “biome”. It has been shown that the term can be interpreted in many different ways, each leading to a different classification system. There is a reasonably complete agreement among the sources that biomes should be identified by the prevailing vegetation and/or (macro)climatic parameters, and should represent large units. At the same time, there are indications that other factors (such as land use considerations) may play a role.

36. This section outlines some possible options for the development of the biome scheme. The advantages and disadvantages of three main scenarios are presented, while it is acknowledged that many more are possible. The likelihood for the adoption of the various scenarios is also considered.

1. Parties use their own national systems of ecological zoning

37. Under this scheme, Parties could use their own biome definitions. These definitions would have the same structure as the current ones, but different threshold values might be selected. Forest definitions would be assigned to biomes permanently.

38. Advantages: Most countries have appropriate national methods for classifying forests in ecologically meaningful units. National categories are likely to describe local peculiarities best. Maps are already available in sufficient scale. Implementation at the national level would be inexpensive.

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9 FCCC/SBSTA/2000/MISC.6/Add.2.

10 FCCC/SBSTA/2000/9 paragraph 27.

39. Disadvantages: Comparability of data and the transparency of reporting could be compromised. Expert review teams would have to scrutinize the appropriateness of the national classification system. Dispute resolution might be difficult. Similar areas on the two sides of national boundaries could fall into different categories, leading to serious inconsistencies.

40. Such a system, in its "pure" form might be difficult for Parties to implement. However, national zoning systems, or at least elements of them, might be used for some countries, especially bigger ones, and ones where consistency across boundaries is a lesser problem (e.g. some island states). It may also be the method of choice for dealing with relatively small, but very distinct, systems, which are difficult to categorize properly at the international level. Most notable are the various mountain systems, with a high diversity of habitats in relatively small areas.

2. Parties decide to develop a completely new global zoning system for the purposes of the Kyoto Protocol

41. As none of the existing classification systems was designed specifically for the purposes of carbon inventories/accounting, arguments could be made for the development of an entirely new system, specifically designed to serve the needs of the Kyoto Protocol.

42. Advantages: such a system, at least theoretically, could serve the needs of the Convention. It could take advantage of the latest scientific knowledge on carbon dynamics and other related areas. It could be developed at the right scale, and it could be expected to minimize inconsistencies.

43. Disadvantages: the scientific, organizational and financial requirements of such a project are likely to be prohibitive, especially since it would serve just one component of the system created by the Kyoto Protocol.

3. Parties adopt (with appropriate adjustments, if necessary) an existing global classification system, or several regional ones

44. Many zoning schemes have been developed for the classification of land into ecologically meaningful units; they represent a broad range of scales and level of detail, from the regional to the global. Most of these were developed on the basis of macroclimatic elements and floristic characteristics.

45. The most important regional systems include that of Bohn *et al.* (2000) for Europe and Bailey (1998) for North America. Holdridge (1947) developed several national vegetation maps for Latin America, based on his system which makes use of evapotranspiration data, in addition to temperature and rainfall.

46. Global systems include that of Köppen (1931), which was later modified by Trewartha (1968). More recent efforts include a global ecoregion map developed by WWF (WWF, 2000). A review of all existing systems would go beyond the limitations of this report, but a list of the most important references is provided in appendix A (based on FAO, 1999). A detailed review of the available classification systems can be found in FAO (2000).

47. An advantage of adopting an existing system is that no major effort is required to develop/adapt the system. Furthermore, most systems enjoy a degree of acceptance, and their benefits and shortcomings are known.

Disadvantages: existing systems were developed for purposes other than carbon accounting, and their applicability for implementation of the Kyoto Protocol is limited. Regional systems may require significant harmonization efforts (at least in the regions where they meet/overlap). Global systems tend to be better suited for some areas/continents than for others, either because they were first developed with one region in mind, or because of uneven data availability; so it may be difficult to have them accepted by all Parties. Most earlier maps exist only in hard copy, and only with relatively modest accuracy, so georeferencing and the refinement of the boundaries of the biomes may pose significant problems.

49. Should Parties decide to introduce biome-specific forest definitions, it is likely that they would need to adopt one or more of the existing classification systems, probably with some modifications. The global ecological zoning system of FAO (FAO, 2000) has overcome most of the above difficulties, and deserves special attention as it is the best system yet for consistent global classification of forest type. It is reviewed in more detail in the following section.

C. Global ecological zoning for the Forest Resources Assessment 2000

50. The GEZ map, developed for the FRA 2000 report (FAO, 2000) is presented here in more detail, as it is a good example of a comprehensive, global classification of ecological zones. It appears to be the best system developed to date.

51. Characteristics and components of the FAO GEZ classification include the use of the Köppen-Trewartha system (Trewartha 1968), with some modifications, in combination with vegetation characteristics, as a basis for the delineation of zones. The GEZ classification system has a hierarchic structure: at the broadest level five domains are distinguished, which are subdivided into 20 “ecological zones”. The mapping work was carried out principally using regional or national potential vegetation maps to define boundaries of ecological zones at the global level. Regional experts and scientists provided support and advice. Although using a variety of input maps inevitably caused methodological problems such as edge matching across adjacent maps, a protocol for correcting such problems was successfully developed and implemented. In addition to the global EZ map, regional descriptions were prepared on the vegetation, climate and physiography of the ecological zones. The GEZ used the following definitions (FAO, 2001):

(a) **Ecological zone:** Defined as a zone or area with broad yet relatively homogeneous natural vegetation formations, and similar (not necessarily identical) physiognomy. Boundaries of the ecological zones coincide approximately with Köppen-Trewartha climatic types, which are based on temperature and rainfall. An exception to this definition are "mountain systems", classified as one separate ecological zone in each domain and characterized by a high variation in both vegetation formations and climatic conditions.

(b) **Domain:** Broadest entity or level in classification, equivalent to the five thermic Köppen-Trewartha climatic groups and including the tropical, subtropical, temperate, boreal and polar domains.

52. The five domains are divided into a total of twenty ecological zones. A full list of GEZs with brief descriptions is given in appendix B. The benefits of the GEZ system for the purposes of Article 3.3 include the following:

(a) It is the most recent of such systems;

(b) It was developed specifically for forestry purposes (unlike some other systems, which were developed for scientific or conservation purposes), and so it is likely to be well adapted for Article 3.3;

(c) It was developed by many experts in a collaborative effort representing a good regional balance, and was developed under the sponsorship of a United Nations agency, which is likely to increase its political acceptability;

(d) Its mapping was carried out using GIS technology, making the maps easy to use and to manipulate;

(e) Its hierarchical system allows "biome" to be defined either as a top-level category (equivalent to the "domains" of the GEZ), or as a second-level one ("ecological zone"):

53. Some of its limitations are:

(a) The base scale of the GEZ map is 1:1 million. While this is sufficient for global-level analysis, it may be insufficient for the accurate identification of ARD land on a local scale;

(b) There are regional differences in the accuracy of the source maps (despite all efforts to use the most precise source maps);

(c) Small ecological zones could not be properly classified. Most importantly, mountain systems are delineated as a separate zone at level 2 in all but one (polar) of the five domains, but they are not classified in detail. As mountain systems tend to have a high degree of habitat diversity (e.g., lush rain-forest and bare alpine rock can exist within a very short distance from one another), a single forest definition for mountain forest may not be appropriate. A resolution of this (perhaps at the regional/national level) is likely to be necessary if the system is to be adopted.

D. Conclusions

54. In summary, it is not easy to determine what kind of biome classification system could be adopted as the basis for biome-specific forest definitions. There is no single accepted definition for the term "biome". The word has been used interchangeably with several related words and expressions, representing a wide range of different concepts from the crudest division of the land surface of the Earth (into no more than three classes) to the most detailed floristic classification of certain regions.

55. Existing classification systems tend to rely mostly on macroclimatic parameters, potential vegetation type and physical features. These parameters allow the permanent delineation of biomes, discounting the possibility of significant shifting of biome boundaries due to climate change or other environmental change.

56. At least some proponents of biome-specific forest definitions have proposed that some biome categories (such as "agroforestry" or "plantations") should be defined on the basis of land use. As land use can and does change relatively quickly, such a system would not allow the consistent and permanent categorization of land. For this reason, it would be very difficult to factor land use considerations into the definition of biomes.

57. Parties may arrive at an acceptable set of biomes in different ways. The primary options are summarized in table 1.

Table 1. Overview of the primary options for the possible adoption of a biome classification system

Options	Advantages	Disadvantages
Parties use their own national systems of ecological zoning	- Well adapted to local conditions - Systems readily available, generally at an acceptable resolution - Some relevant statistics may be available according to classification	- Inconsistencies between systems (countries) - Systems not developed with carbon accounting in mind - Difficult to monitor/review application

Options	Advantages	Disadvantages
Development of a new global zoning system specifically for the purposes of the Kyoto Protocol	- Optimal performance can be achieved - Carbon dynamics can be taken into account from the beginning - The system can be developed with sufficient detail	- Expensive and time consuming process - Duplication of effort
Adoption of existing regional/global system(s)	- Well adapted to the given area (continent) - Consistent across regions (or even globally) - Available	- Inconsistencies between regional systems - Low resolution - Less relevant for local/national circumstances - Systems not developed with carbon accounting in mind

58. The need for global comparability, consistency and transparency suggests that a global, as opposed to a regional, classification system would need to be adopted. Of the existing global classifications, the GEZ system of FAO, developed for the purposes of FRA 2000, would appear to be the best. However, this system would need refinement and further elaboration, if it is to be used effectively for carbon accounting under the Kyoto Protocol.

IV. FOREST DEFINITIONS

59. The current forest definition under the Kyoto Protocol follows the structure of the FAO forest definition used for the TBFRA (FAO, 1998) by establishing a minimum threshold value for the same three attributes.[11] Renegotiating forest definitions theoretically opens up the possibility of using any definitional scenario, or even different scenarios for different biomes, starting with the second commitment period. Despite this possibility, in this section it is generally assumed that Parties will retain the current structure of the forest definition, changing only the threshold values of the three parameters (i.e. for minimum area, minimum crown cover and minimum height).

60. There are two main reasons for this assumption. First, the resources available for this report did not allow the analysis of the implications of all plausible forest definitions. For the FRA programme, more than 650 definitions of forest were assembled (FAO, 2000). Some of the most representative definitional scenarios are analysed in detail in the SR-LULUCF (IPCC, 2000), and it is unnecessary to repeat the analysis here. Second, on the basis of the Parties' submissions sent before the Marrakesh accords, including those recommending biome-specific definitions, it appears that most Parties prefer the current structure of the definition.[12]

61. The implications of applying different definitions for the various biomes are demonstrated in the GEZs of FRA 2000. This system was chosen as it was considered the best available global classification system, and it is detailed enough for most of the important considerations to be presented.

62. This section presents first the relevance of the three parameters in the various biomes. Then the potential effects of these parameters on ARD activities are investigated.

A. Effect of forest definitions on the estimated forest area

63. When applied to large tracts of closed formations of productive forests, the threshold values used in the definition of forest have virtually no effect on the estimated forest area. The threshold values begin gaining importance as the extremes of the natural range of forest are approached, or when dealing

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[11] But the FAO definition sets firm minimum values for area, height and crown cover (0.5 metres, 5 metres and 10 per cent, respectively), and it explicitly excludes lands that are used predominantly for agriculture.

[12] For an example, see FCCC/SBSTA/2000/9, paragraph 27.

with heavily impacted forests. The impact of the three definitional parameters is reviewed here in the context of the various biomes.

1. Minimum height at maturity

64. The minimum height gains most importance close to the natural tree lines in boreal forests and in mountain areas. The classification of vast areas of boreal forest (mostly tundra) can depend on the minimum height. In the mountains, the affected area is much smaller (limited mostly to Alpine areas near the timberline), although it can be significant locally. The minimum height can also be important for the categorization of some dry forest/shrubland ecosystems, as well as some agroforestry systems. Many countries do not include a minimum height in their forest definition, as it is not considered necessary as long as the type of dominant vegetation (forest tree species) is specified.

2. Minimum area

65. This parameter is best discussed separately for open woodlands (where woody and other vegetation alternate in patches of various sizes) and closed forest formations.

66. In closed forests, using a minimum area threshold is needed for administrative and ecological reasons. Ecological considerations are based on the recognition that for forests to fulfil their various ecological functions and to exhibit their representative structure and dynamics, they have to be of a certain size.[13] There are strong arguments for linking the minimum area to the type of forest, for example as a function of the dominant tree height.[14] For administrative reasons, the minimum area has to be set as a fixed value, but biome-specific definitions should reflect the above considerations.

67. In most temperate and dense boreal (taiga) forests, the impact of the area threshold on the amount of land identified as forest is minimal. A simulation study conducted for 19 EU and EFTA countries estimated the impact of applying various minimum threshold values to the estimated area (EU, 1997). The study found that by varying the area threshold, the forest area of individual countries could be overestimated by up to 10 per cent, or underestimated by up to 6 per cent. If the 10 per cent threshold of the TBFRA-2000 (United Nations, 2000) is used for all countries (which tend to have similar or higher national thresholds, up to 30 per cent), the forest area of the region would be overestimated by only 1 per cent, which is well within the margin of error for the practical estimates of the carbon balance of terrestrial ecosystems.

68. No similar numerical estimates for Russia, North America or other major countries could be obtained. It is likely, however, that the impact of the area threshold would be larger in these cases. The area threshold is likely to be most influential in tundra, steppe, shrubland and dry forest formations.

69. The area threshold is also influential in forests under significant human pressure (encroachment, logging, etc.) Under such conditions, an ecological zoning system can provide the distinction between an open forest formation and a fragmented closed forest formation.

70. In the case of open forest formations, the minimum area requirement cannot always be separated from the canopy cover threshold. While they refer to different spatial scales of assessment (the former being interpreted on a larger scale), there can be a considerable overlap between these scales.[15] The size

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[13] For similar reasons, many countries specify a minimum width (often set as 10 or 20 metres) for forests, to allow the practical classification of shelterbelts, windbreaks, hedgerows and other linear wooded areas common in many cultural landscapes.

[14] As an example, the minimum area could be defined as the square of three times the height of the dominant tree class. This would result in a minimum of one hectare for trees 33 metres tall, and 0.0225 hectare for 5 metres tall vegetation.

[15] For example, 20 dense groups of trees, 1000 square metres each, evenly distributed over a 10 hectare area, could be interpreted as 10 hectares of open forest (with 20 per cent canopy closure) or 2 hectares of closed forest (in 20 stands, surrounded by non-forest), or any combination in between.

restriction can be interpreted as one referring to administrative/ownership/management units, but this is not explicit. A biome-specific approach, if sufficiently detailed, can clarify the interpretation.

3. Minimum crown cover

71. The minimum crown cover can be a limiting factor in many areas where height can be limiting (as discussed above). In addition, it is a very important parameter for classifying open woodlands (dry forest and steppe formations). However, crown cover has a major significance in all forest types, as virtually all disturbances, human induced or natural, have a temporary or lasting effect on crown cover, making it a sensitive indicator of "naturalness" and disturbance.

72. The possible interlinkages between minimum crown cover and minimum area have been mentioned above. As the minimum area parameter acts at a larger scale, crown cover is the most commonly used proxy for assessing the naturalness of closed forest formations and it is the most important simple parameter for detecting degradation of forests.

73. If the crown cover indicates less than full stocking, it is important to make the distinction between reductions due to natural disturbances, to sustainable human activities (e.g. logging with appropriate control and regeneration measures in place) and unsustainable activities leading to the degradation of forest. While these distinctions can be made on the ground, or can be inferred from time series remote sensing images, it is difficult to include such considerations in the definition of the forest.

74. Table 2 summarizes the effect of the threshold value of the definitional parameters on the amount of forest detected in the various biomes.

Table 2: The effect of forest definitions on forest area detected. Signs indicate the expected change in the forest area estimated due to an increase in the given definitional parameter. (- small decrease, - - large decrease, 0 no significant impact. Brackets indicate uncertain effect.)

Classification		**Effect of increase in parameter**		
Level 1	Level 2	**Min. area**	**Min. height**	**Min. crown cover**
Tropical	Tropical rain forest	0	0	0
	Tropical moist deciduous forest	0	0	0
	Tropical dry forest	0	0	-
	Tropical shrubland	-	- -	- -
	Tropical desert	0	0	0
	Tropical mountain systems	(-)	-	(-)
Subtropical	Subtropical humid forest	0	0	0
	Subtropical dry forest	0	0	-
	Subtropical steppe	- -	- -	- -
	Subtropical desert	0	0	0
	Subtropical mountain systems	(-)	-	-
Temperate	Temperate oceanic forest	0	(-)	(-)
	Temperate continental forest	0	0	0
	Temperate steppe	- -	-	- -
	Temperate desert	0	-	0
	Temperate mountain systems	(-)	-	-
Boreal	Boreal coniferous forest	-	-	-
	Boreal tundra woodland	- -	- -	- -
	Boreal mountain systems	- -	- -	- -
Polar	Polar	0	0	0

B. Implications of forest definitions on the detection of ARD activities

75. The previous section presented some of the implications of choosing different threshold values for forest definitional parameters for the area of land classified as forest. From the perspective of carbon cycling (estimating sources and sinks of carbon), changes in forest land are more important than the amount of forest itself. For this reason, ARD activities receive special attention in the Kyoto Protocol. This section presents the implications of some definitional choices for the detection of ARD activities.

1. Afforestation/Reforestation (A/R)

76. As they are currently defined in the Marrakesh accords, there is no difference between afforestation and reforestation in the context of Article 3.3. Both assume the creation of forest in an area that did not contain forest on 31 December 1989. It should be noted that afforestation includes, and in some interpretations is limited to, the establishment of forest on areas that historically/naturally had, never before contained forest. In a biome-based system, it might be conceptually difficult to define the required attributes of a forest for an area that is naturally treeless.

77. It normally takes several to many years from the initial A/R activity before the vegetation established meets or exceeds the minimum values of the parameters set in the definition of forest. This is recognized in the current definition of forest, which includes young natural stands and plantations if they are expected to revert to forest.

78. Setting the minimum tree height too high can effectively preclude A/R activities in certain areas characterized by low vegetation, as was discussed in 3.1.1. Although such areas are likely to be of low productivity and are likely to be less attractive for the purposes of carbon sequestration activities (e.g. revegetation of Alpine zones with dwarf pines, *Pinus mugo*), there are areas where carbon credits could be considered a significant incentive for undertaking A/R activities (e.g., restoration of temporarily inundated riverine willow communities).

79. Minimum area is largely irrelevant in this context. Setting the minimum area high can disqualify some small plantings (e.g. schemes encouraging revegetation activities on small farms) from the A/R category, but such effects are not likely to be biome-specific. In open formations, where the characteristics of the vegetation could prevent the establishment of contiguous forests of sufficient scale, the size requirement can be limiting if there is a high threshold for crown cover (see section 3.1.2 on the link between the two parameters).

80. Minimum crown cover can be an important factor in the determination of areas under A/R. On the one hand, a high value can block some open formations from being eligible for A/R projects. Although these areas are likely to be less productive (see 3.1.3), there might be strong arguments (social and environmental) for considering them for reforestation. On the other hand, sufficient crown cover is a major success indicator for young forests. Setting the value too low for closed forest formations could allow less than fully stocked young stands to get credit for A/R, which could raise questions about the environmental integrity of the system. However, this is unlikely to be a major risk, as those establishing new forests are usually genuinely interested in the success of the plantings. Furthermore, environmental performance can be assured in other ways (through national policies for many countries, and provisions in the CDM for non-Annex I countries, providing safeguards for environmental integrity).

2. Deforestation

81. Deforestation often occurs quickly, through the harvesting (or other sudden loss) of forests, followed by land-use change. However, gradual forest loss (degradation) can also lead to deforestation. Under current rules, deforestation is considered to occur at the moment the forest no longer meets the

definitional criteria, even though its degradation may have started much earlier. These concepts are illustrated in figure 1, using crown cover as the threshold criterion.

82. When deforestation occurs abruptly (as in the case of clear cutting or burning), the change is normally obvious, and the actual threshold values do not make a difference. However, when forest loss occurs through gradual degradation, the threshold can have important implications.

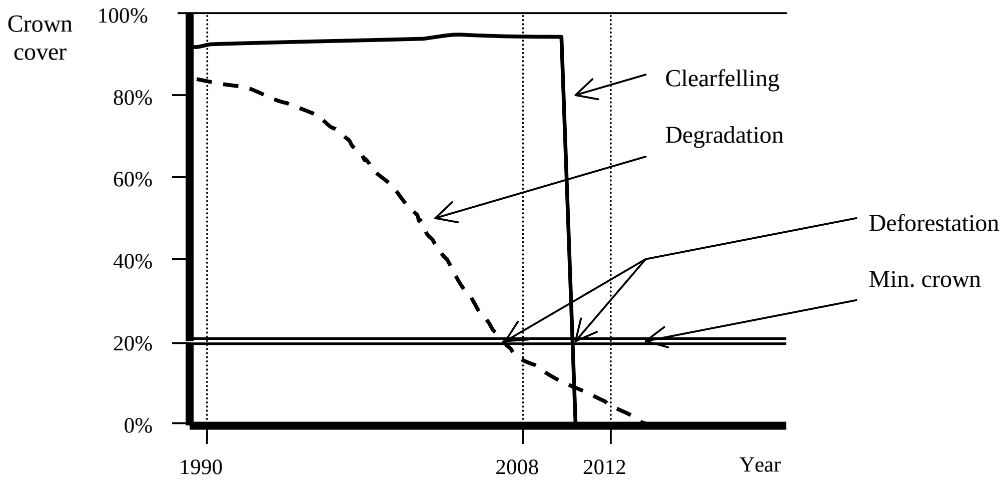

Figure 1. Sudden forest loss and degradation. Degradation is registered as deforestation only years after the process started.

83. Minimum tree height is normally not relevant as an indicator of deforestation, even when the tallest trees are harvested first. The minimum forest area can be important in some settings, where degradation occurs through fragmentation, resulting in isolated groups of trees. In most cases, nevertheless, the best indicator of degradation is the loss of crown cover.

84. For degradation to trigger the definition of deforestation at an early stage, it has been recommended that a relatively high crown cover threshold be used for closed forest formations prone to deforestation. This could ensure that significant carbon losses would be accounted for under Article 3.3. While this is true for reasonably intact forests, however, such a measure could have just the opposite effect for forests already degraded to some extent, as demonstrated on figure 2.

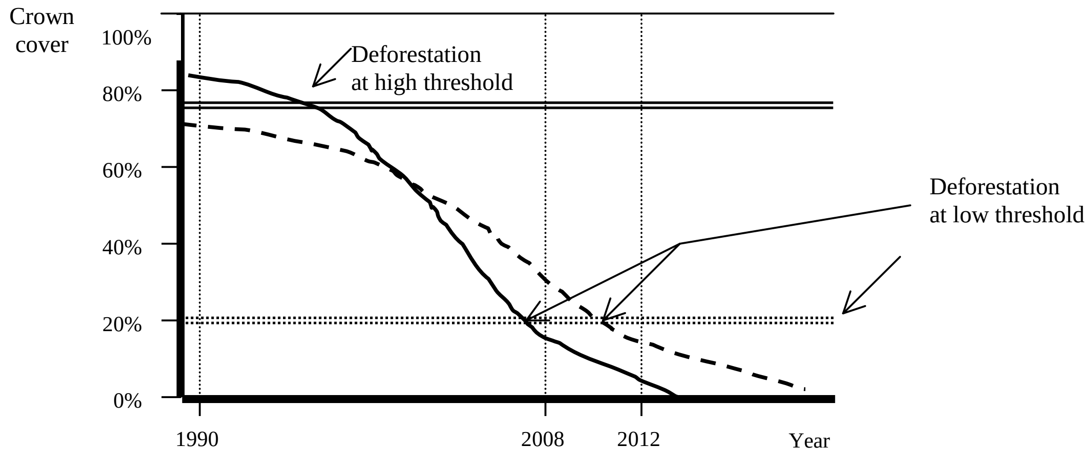

Figure 2. *Forest degradation at different crown cover thresholds. While continued degradation always triggers deforestation at a low threshold, a high threshold is efficient only if degradation starts at a nearly full stocking level.*

C. Conclusions

85. Analysis of the effect of the minimum values of the definitional parameters on the amount of land identified as forest or as land affected by ARD activities in the various biomes provided few conclusive results. In general, in reasonably intact closed forests there is little difference between the definitional scenarios. In more marginal communities, the values selected can significantly affect the amount of land classified as forest and/or the likelihood of ARD activities to be eligible/detectable.

86. In closed forest formations, the minimum area parameter is important mainly for administrative reasons. In open formations (and heavily fragmented forests) it can be important in effectively defining forests. However, the effect of this parameter is somewhat similar to that of the minimum crown cover value, and the two should be considered in conjunction.

87. Minimum crown cover is the criterion most directly linked to forest quality (naturalness/degradation); thus it is also the most debated one.[16] A low threshold value leads to the acceptance as forest of some sparsely wooded areas of low productivity, as well as severely degraded stages of more productive formations. While this can raise environmental concerns, a higher threshold may create similar problems by failing to capture the disappearance of forests already under the threshold.

88. No strong arguments have been identified either in favour of or against defining forest on a biome-specific basis. Left unchanged long enough, any reasonable definitional scenario will detect major trends in transitions between forest and non-forest areas. As long as the system is based, in any one place, on a set of threshold criteria, its sensitivity (its ability to detect small changes) can be increased not so much by changing the definition, but by reducing the size of the spatial assessment units.[17]

[16] Stephen Kelleher and others, WWF, personal communication.
[17] Eveline Trines, personal communication.

V. IMPLICATIONS OF CHANGING FROM THE CURRENT FOREST DEFINITION TO A BIOME-SPECIFIC ONE

89. It would be premature to speculate as to the potential aggregate effect of switching from one definition to a set of new, biome-based definitions, as the nature of the possible new definitions is not yet known. It is, however, possible to summarize the types of problems and scenarios that may result from a changeover from one definition to another, and the steps necessary in order to reduce negative impacts.

A. Reporting national data under new definitions

90. First and foremost, a changed definition will require the modification of existing methods for the estimation of forest land. Between the first and second commitment periods, the way the forest area is estimated will have to be changed. For example, in country A the national forest definition specifies a 20 per cent minimum crown cover, which is what this country chose to use for the first commitment period under the Kyoto Protocol. If the new forest definition specifies a 40 per cent minimum crown cover, then the national inventory figures will have to be adjusted (downwards, if other factors remain unchanged). Should the country include more than one biome with different forest definitions, the adjustment will be more complicated since the national inventory will have to be divided along the biome boundaries (which may not coincide with any national system), and then the adjustments will have to be made to the various biomes.

91. Most countries (probably all) use a single forest definition for administrative purposes, and their instruments (maps, inventories, models, regulations) have been designed to work with that definition. Generating data that match a different definition is likely to cause at least some difficulty for all countries, and these problems may be grave for some. Certain adjustments may be relatively easy to make. In countries with detailed inventories it might be possible to use a different definitional scenario by simply running a different query on the national database.

92. Most countries already have some experience in reporting detailed data on the basis of definitions other than the national one. FAO (and, for developed countries, UN-ECE) has for decades been collecting forest-related information from all countries. As the current definition under the Kyoto Protocol is very similar to that used by FAO (FAO, 2000), countries might be able to make the necessary adjustments with reasonable effort. It should, however, be noted that FAO and UN-ECE have been reporting significant problems with data quality and reliability. This might be, in part, due to the poor national data of some countries. Nevertheless, much of the error can be attributed to adjustments from one definition to another.

93. Assuming that the second commitment period will immediately follow the first, for the end of the first commitment period, the forest area will have to be estimated by both the old and the new methods. It will be shown below that for some areas it might be necessary to continue the use of both the old and the new definitions for an indefinite period of time.

B. Accounting problems

94. A change in forest definition is likely to result in a reclassification of at least some land from forest to non-forest class, and/or from non-forest to forest. It means that the overall forest area is likely to change without the involvement of any ARD activity. The land categories so created are demonstrated by means of a simple example involving changing two parameters (figure 3). This change in forest land will have to be separated from any due to ARD activities, which raises several questions regarding reporting and reviewing procedures.

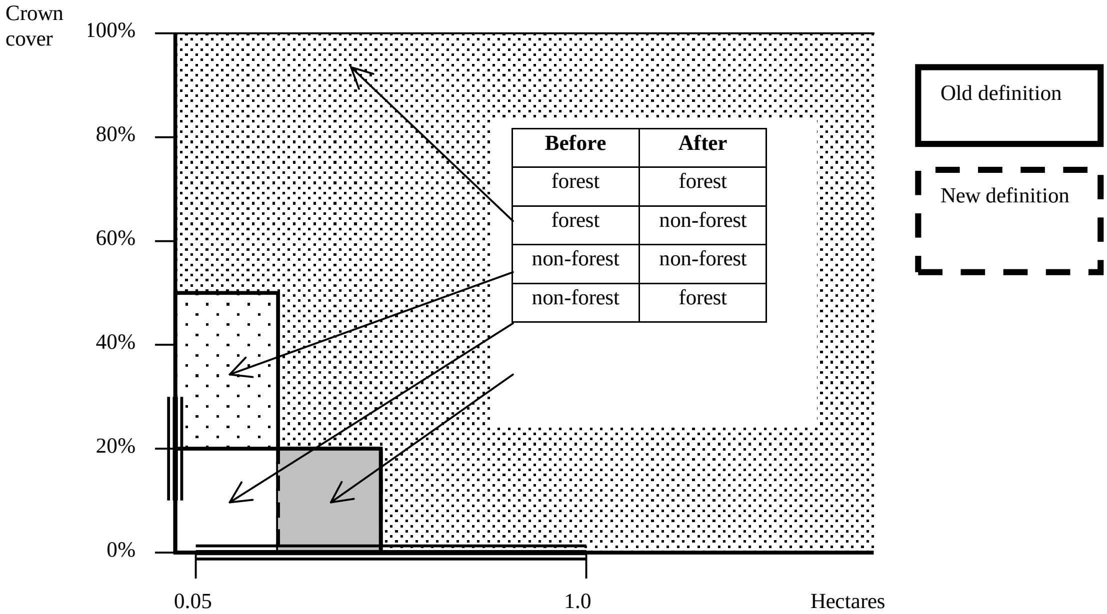

Figure 3. An example of land categories created by a change in forest definition. The minimum crown cover was raised from 20 per cent to 50 per cent, while the minimum area was reduced from 0.5 hectare to 0.25 hectare.

95. The following sections discuss a number of simple but plausible situations which may result from changing definitions. They assume a change in one of the three definitional parameters (crown cover was selected). The change leads either to a more restrictive definition (by raising the minimum canopy cover), or to a more liberal one (by lowering the threshold).

1. Partitioning forest loss

96. The simplest scenario, with no actual change in woody vegetation, only a single definitional change, is demonstrated in figure 4. The area covered with 40 per cent woody vegetation will be "lost" from the national inventory. Situations like this might be relatively easy to handle, as the actual amount of woody vegetation is unchanged, and the statistical difference can be entirely attributed to the change in definition (there should be no debit for deforestation). However, the picture is more complicated when the definitional change coincides with an actual change in woody vegetation.

97. Figure 5 demonstrates a scenario where definitional change is implemented during a steady degradation of the vegetation. While neither deforestation, nor the change in definition, in or by themselves, would be enough to trigger "deforestation", the combined effect is a loss of area qualifying as forest. This is likely to be a rather common scenario, should the minimum canopy closure requirement be raised for closed forests which are under strong deforestation pressure.

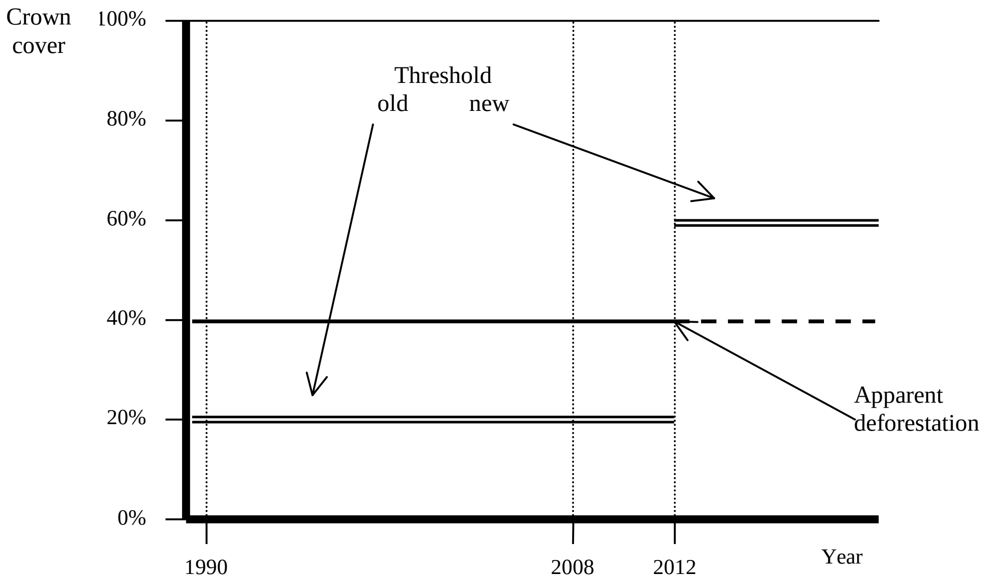

Figure 4. Change in forest definition (from 20 per cent to 60 per cent minimum crown cover). Amount of woody vegetation unchanged at 40 per cent, which qualifies as "forest" in the first commitment period, but not afterwards.

98. This raises the problem of how to partition the apparent loss of forest. Although it is the definitional change that ultimately triggers the reclassification of the area, this would not happen without the occurrence of continuous degradation for some years before 2012. The problem is compounded by the fact that not all forests can be inventoried at the moment of definitional change, which means that the actual forest cover on 31 December 2012 can be determined only by modelling techniques which are likely to incorporate some subjective elements.

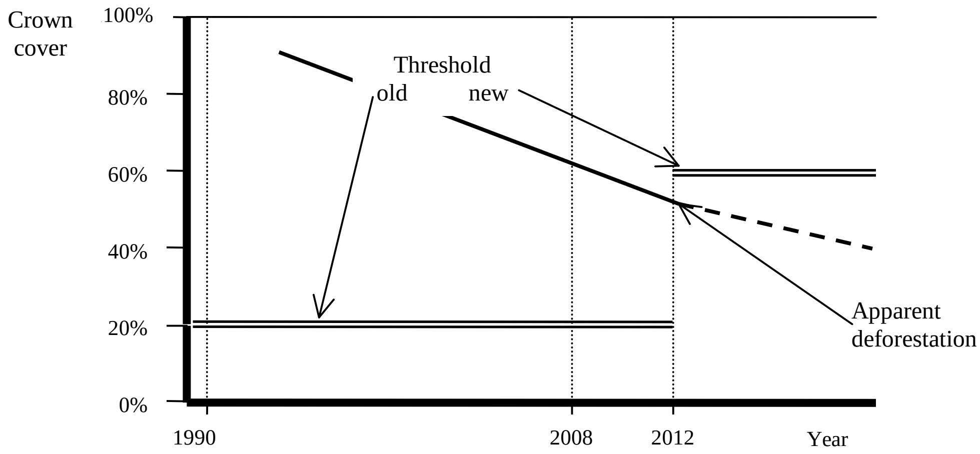

Figure 5. Change in forest definition (from 20 per cent to 60 per cent minimum crown cover). Amount of woody vegetation in steady decline. Apparent forest loss needs to be partitioned between causes.

2. Afforestation issues

99. A hypothetical afforestation project (which could be the restoration of an open forest type, or the establishment of an agroforestry system) aims at achieving 50 per cent forest cover in 10 years (figure 6). Initiated in 2000, with a minimum crown cover requirement of 20 per cent at maturity, the project qualifies as afforestation. However, if it is initiated in 2010, its status is questionable. Although at the time of planting the same definition applies as before, the threshold changes before the trees reach the minimum height. The main question here is when the new definition becomes effective in the case of immature, developing stands. While this is unlikely to create problems with carbon accounting (as the land would be registered as "ARD land", regardless the status of the area), it can lead to odd situations where an afforestation project, although successfully implemented, never actually results in forest.

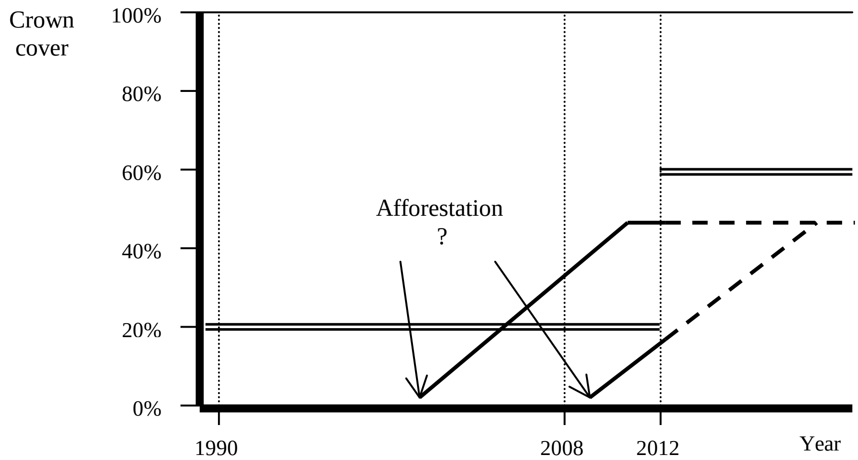

Figure 6. Change in forest definition (from 20 per cent to 60 per cent minimum crown cover). Afforestation is carried out, aiming at the development of an agroforestry project with 50 per cent crown cover in 10 years.

C. Potential loopholes, perverse incentives

100. A change in definition can open up a number of loopholes for those who might try to abuse the system. Similarly, it can create opportunities for avoiding debits or claiming extra credits by simply bringing forward or postponing some activities, perhaps only on paper.

101. In figure 7, a well-stocked natural forest is to be converted to other land use in 2013. This would be considered deforestation under any definition. However, deforestation debits could be avoided (at least theoretically), by bringing forward the beginning of the operation by a few months, reducing the crown cover to around 30 per cent before the end of the first commitment period. The area would then be reclassified as non-forest (due to the change in definition, no debits). The remaining trees could then be harvested from the area without its qualifying for deforestation.

102. In a similar case, the new forest definition is assumed to be more liberal than the old one (figure 8). A degraded forest, with about 20 per cent canopy cover remaining, is about to be reclassified as forest, due to a change in definition (changing the threshold from 30 per cent to 10 per cent). Seeing that unavoidable further degradation will result in deforestation, the land manager allows the clearing of the remaining vegetation before this counts as deforestation.

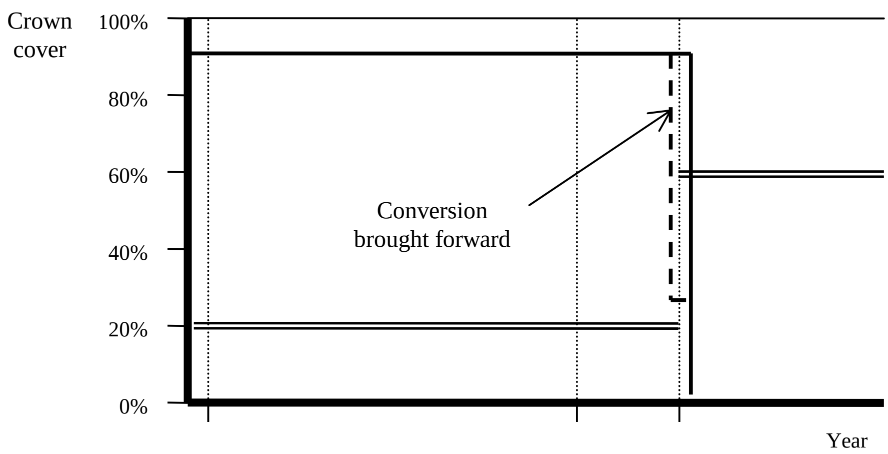

Figure 7. Forest conversion brought forward to avoid deforestation debits.

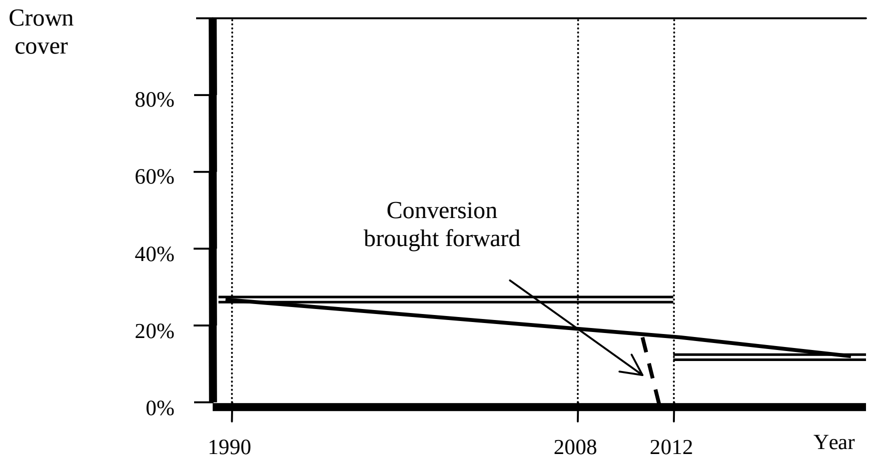

Figure 8. Forest conversion brought forward to avoid deforestation debits.

D. Conclusions

103. Changing the applicable forest definition from one commitment period to the next is likely to create considerable difficulties for Parties in their reporting. It can introduce a new source of error into the conversions, making it even more difficult to calculate changes in carbon stocks over time reliably. This factor alone can raise questions about the wisdom of changing definitions.

104. In addition, different definitions will result in areas changing status (from forest to non-forest or vice versa) solely or partly due to the definition change. Modalities will have to be developed to allocate the change in forest area to various causes.

105. Predictable changes in how forests are defined can open up loopholes or provide incentives to circumvent the system. Most of the above scenarios describe cases which can be prevented by proper formulation of the changeover. However, the range of possibilities is endless. It should also be pointed out that the bigger the difference between the current and the future definitions, the more opportunities and incentives there are going to be to circumvent the system. Such opportunities may be limited if the new system is only slightly different from the current one. In that case, however, it is questionable whether changing the system is justified.

VI. CONCLUDING REMARKS

106. There is no clear guidance regarding the possible interpretation of "biome" in the given context. Parties could choose to develop a new "biome" classification system for the purposes of the Kyoto Protocol. However, the development of an entirely new system would require considerable time and resources.

107. Alternatively, Parties could adopt one or more of the many global, regional and national ecological zoning systems that already exist. All of these have certain weaknesses, and their application may cause considerable methodological and political difficulties; so they need to be adapted.

108. There is a trade-off between the level of detail (ecological representation) and cost (time and resources needed for development). A coarse system (such as one that defines only five biomes based on macroclimatic parameters) may be easy to define and apply, but it will be unable to reflect local variations in vegetation, productivity and other parameters, and thus it is likely to have significant inconsistencies within and between biomes. A refined system, operating with hundreds of ecological zones, is likely to reflect ecological variability better, but it is likely to be difficult to design, negotiate and implement. Any system developed on a global scale will have significant inconsistencies at the local (forest stand) level.

109. Of the existing classification systems, it is the GEZ system, developed by FAO for the FRA 2000 report, which appears to be the most appropriate for adoption, as it was developed for forestry purposes, it builds on the most widely accepted precedents, it is well harmonized between countries and regions, it is of relatively high resolution and it is available in digital format. It is also likely to be the most acceptable politically.

110. Forests have been defined in hundreds of different ways. International precedents and the submissions of proponents of "biome-specific forest definitions" suggest that such definitions would continue to rely on a combination of the same basic parameters as the current definition, namely: minimum area, minimum tree height at maturity, and minimum canopy cover (or another appropriate measure of density).

111. The values of the above parameters can influence the amount of land that is classified as forest. The effect of these parameters on the amount of land classified as forest seems to be greatest towards the

margins of the natural distribution of forests, and in areas highly impacted (disturbed/fragmented) by human beings.

112. Similarly, a change in forest definition can affect the amount of land detected as afforested/reforested or deforested. However, the net effect of the definitional change on the amount of land under ARD activity cannot be generalized, as it depends on numerous factors.

113. In general, each country uses one single forest definition for inventory and administrative purposes. The introduction of biome-specific forest definitions, unless the "biome" boundaries follow country borders, will require at least some countries to use multiple forest definitions for their reporting, which may cause considerable methodological problems and inconsistencies.

114. There have been no strong arguments identified either in favour of or against defining forest on a biome-specific basis. Left unchanged for long enough, any reasonable definitional scenario will detect major trends in transitions between forest and non-forest areas. As long as the system is based on a set of threshold criteria, its sensitivity (its ability to detect small changes) can be increased not so much by changing the definition, but by reducing the size of the spatial assessment units.

115. A change in the forest definition is likely to cause difficulties with carbon accounting, as at least some of the land will have to be reclassified (from forest to non-forest or vice-versa). Separating real change in the amount of forest from apparent change due to a different definition may be difficult not only in practice, but even theoretically. This may complicate inventories, can make reviews more difficult and is likely to create loopholes and negative incentives which have to be carefully considered before a decision on a change in definition is made.

116. It should be mentioned that some of the above problems may emerge without the introduction of biome-specific forest definitions. The forest definition negotiated for the first commitment period allows countries to set their own minimum values, within the range specified, for the three threshold parameters. While this selection cannot be changed for the first commitment period, the decision leaves open the possibility for countries to choose another set of minimum values for the second commitment period. Parties may want to decide to remove this possibility, in order to improve the integrity of the system.

117. Finally, it should be emphasized that this paper has focused on the (change in the) definition of forest, that is, the implications of how forest land is differentiated from non-forest land. It assumes that all land classified as "forest" will be treated similarly, and does not consider the possibility of using different carbon accounting methods in the forests of different biomes. There could be strong arguments for requiring different inventory/carbon accounting methodologies for different forest types. For example, it could be argued that for those vegetation types where much of the terrestrial carbon is contained in the soil (most boreal forest types, for example), carbon accounting should always include the carbon pool of the soil. However, such considerations (which could be described as biome-specific carbon accounting) would go far beyond the limitations of this study, and would require a fundamentally different approach.

Annex I

Review of existing global ecological zoning systems

This annex is based on the review prepared for the FAO Forest Resources Assessment 2000 Report (FAO 1999). It lists, and gives some relevant particulars about, the most important global climate, ecological zone or potential vegetation maps that were available before the GEZ System of the FRA was developed.

The global maps described below primarily define climatic ecological zones. Two of them particularly emphasize differences in biogeography or species origins: the Udvardy (IUCN-UNESCO MAB) map and the WWF-US maps. Some regional maps also emphasize the biogeographical/ phylogenetic aspect. Regional maps which show vegetation types but do not emphasize ecological zones are not included in these descriptions but are listed at the end of this annex.

Map of Köppen and Trewartha's climate classification (Köppen, 1931, Trewartha, 1968)

A digital map usable at a scale of 1:30,000,000 is available though FAO. No details are available on the origin of this map, which shows five major Köppen climatic types: Polar, Cold, Temperate (humid), Tropical (humid), Dry. A number of subclasses are distinguished, which brings the total number of categories mapped to 14. Because many of the ecological zone maps described below use some major climatic criteria to distinguish their classes, it is deemed worth the effort to list Köppen’s climatic classes for the globe; these are: E (polar climates with extremely cold winters and summers) subdivided into ET: tundra, EF: frozen; D (moist mid-latitude climates with cold winters) subdivided into DF: wet all seasons, DW: dry winters; C (moist mid-latitude climates with mild winters) subdivided into CF: continually moist subtropical, CW: winter dry sub-tropical, CS: summer dry subtropical (Mediterranean); B (dry climates with deficient precipitation during most of the year) subdivided into BS: semi arid, BW: desert; A (tropical moist climates) subdivided into AF: continually wet tropical, AM: tropical monsoon, AW: seasonally dry tropical. These classes are fairly coarse and do not always correspond directly with other Köppen classes used in the literature.

Map of Holdridge’s life zone system (Holdridge, 1967)

Holdridge’s work was aimed at correlating world plant formations by means of simple climatic data. The system embraces all major environmental factors in three hierarchical tiers.

Level I – The life zone. This is determined by specific quantitative ranges of long-term average annual precipitation, mean annual biotemperature and potential evapotranspiration ratio. These are modified for montane systems.

Level II - The association. This is an area of land which, under undisturbed conditions, supports a distinctive natural community adapted through evolution to a specific narrow range of atmospheric and edaphic conditions. No Association can occur in more than one Life Zone.

Level III – The successional stage or cover type, which takes into account that the community may not be in its climatic state, either through natural causes or through human intervention.

A map of the Level I life zones of the globe is available in digital form, usable at a scale of 1:30,000,000. It is, however, raster-based and quite coarse. It was prepared by Rik Leemans, who was then working in the Biosphere Project in IIASA, Laxenburg, Austria. The mapped classification does not differentiate montane communities as such but uses the major cooler climatic types to denote the montane progressions. This map was used for the non-tropical areas of the world in an exercise by the World Conservation Monitoring Centre (WCMC) and the Center for International Forest Research (CIFOR) to investigate global forest protection by forest type and ecological zone (Iremonger *et al.,* 1997).

There are many national maps available for Life Zones, particularly in the Americas.

Map of Walter's zonobiomes (Walter and Box, 1976, Walter, 1979)

This is a map setting out an ecological classification of the world's climates. It is based on the climate-diagram pattern of Walter, in which temperature and rainfall are correlated to show periods of aridity and humidity, in relation to plant growth. Also taken into account are numbers of frost days and other extremes which influence vegetation patterns. There are nine different major zonobiomes, which have modifiers added if they are particularly dry, cold or wet. The map is only available in hard copy, at a scale of 1:30,000,000. The continents are shown as distinct entities on the map, and not joined into one complete global picture.

Walter's work on the zonobiomes goes beyond what is mapped, describing the different major variants within the zonobiomes, named pedobiomes and orobiomes (edaphic or altitudinal factors).

Ecotones between the major zonobiomes are also described.

Bailey's ecoregions map of the world (Bailey, 1989, 1998)

The purpose of this work, which began in 1976, was to show how the national forests of the United States fit within the global ecoregional scheme. In this system an ecoregion is defined as any large portion of the Earth's surface over which the ecosystems have characteristics in common. There are three levels in this classification system, the Domains, the Divisions and the Provinces.

Ecoregions of the continents are based on macroclimate (that is, the climate lying just beyond the local modifying irregularities of landform and vegetation). The theory behind the approach is that macroclimates are among the most significant factors affecting the distribution of life on Earth. As the macroclimate changes, the other components of the ecosystem change in response. Macroclimates influence soil formation and help to shape surface topography, as well as affecting suitability for human habitation.

Four Domains were defined: Polar, Humid temperate, Humid tropical and Dry. The combination of temperature and rainfall to indicate major climatic zones was based on Köppen and Trewartha's work, where dry climates were treated as a separate entity from tropical humid and temperate humid. However, the Köppen system defines an additional "Subtropical" division at this level.

The next level in the Bailey system is the Divisions, and these are also climate-based: for example, in the Humid temperate Domain there is Hot continental, Warm continental, Subtropical, Marine, Prairie and Mediterranean, all with Mountain variants (that is, a total of 12 Divisions in this Domain). There are a total of 30 of these.

The third and last level is the Provinces, which are based on physiognomy of vegetation, modified by climate. For example, the Forest-Meadow of Eastern Oceanic (Monsoon climate). There are a total of 98 of these subdivisions.

The global map has been digitized and converted to a geographic (lat./long.) projection by the WCMC, Cambridge, UK. It is also available on CD from NOAAs National Geophysical Data Center in

Boulder, Colorado as part of their Global Ecosystem Database Project (http://www.ngdc.noaa.gov/Store/).

Bailey has also drawn a more detailed map of the ecoregions of North America. This uses the same system as the global map and defines 63 Provinces. All maps are available in paper form from the author. Robert G. Bailey, USDA Forest Service, 3825 E. Mulberry St., Fort Collins, CO 80524, USA (e-mail: rbailey/wo_ftcol@fs.fed.us).

Milanova and Kushlin's map of present day landscapes (Milanova and Kushlin, 1993)

This was prepared using existing maps also produced by Moscow State University, "Geographical belts and zonal types of landscapes of the world" and "Land use types of the world", as well as remote sensing imagery and sample field observations. The world is first divided into temperature-defined zonal belts and one intrazonal belt, thus: Polar, Subpolar, Temperate, Subtropical, Tropical, Subequatorial, Equatorial and Intrazonal (8 divisions).

Within these are the Landscapes, which are primarily based on the natural land cover and its associated soil type. There are 39 of these, which are the most useful units on this map for the FRA ecological zoning exercise. Each polygon representing one of these types is then given a letter indicating degree of alteration - whether it is virtually undisturbed (“Modal Landscape”), with moderate interference (such as secondary vegetation), with strong interference (crop cultivation) or with extreme change (such as towns).

The map is available digitally and in hard copy from Moscow State University. Copies are also held in the WCMC, Cambridge.

Olson and Watts' map of major ecosystem complexes (Olson and Watts, 1982, Olson *et al*, 1982)

The purpose of this map was to attempt to quantify carbon in live vegetation. The primary division in the mapped classes includes a mixture of criteria: plant formations, edaphic factors (a wetland class is distinguished) and areas altered by human activity. This map is not considered to be one of the principal sources of information contributing to the ecological zoning system of the FRA, because it maps actual land cover rather than potential.

It was originally printed at a scale of 1: 30,000,000, and is available digitally from WCMC, Cambridge.

Udvardy's map of the biogeographical provinces of the world (Udvardy, 1975)

This map was prepared by IUCN as a contribution to the UNESCO MAB programme. The main purpose of the work was to devise a satisfactory classification of the world's biotic areas for purposes of conservation. It is the fourth attempt in a series of revisions, updating the previous three works written by Dasmann.

The logic behind the system was that the plant and animal world occurs within the biosphere of the Earth in the form of an intertwined network of individuals, populations and interacting systems. To be able to view them in a systematic way, the biologist may use the following approaches:

1. Taxonomic order

2. Ecological order

3. Phylogenetic order (origins and history)

4. Biogeographic order - grouping the above entities on a geographic basis.

To define geographic units for conservation purposes, the following were considered: (a) the distribution of species and (b) the distribution of ecosystem units. The result was a system serving both aims, a hierarchical system of geographical areas which would give a framework for conserving species as well as ecologic areas. These hierarchical biogeographical entities were named Realms, Biomes and Provinces.

The first subdivision, the Realm, used the phylogenetic subdivisions of the world, unifying those for flora and fauna. It is a continent or subcontinent-sized area with unifying features of geography and flora/fauna/vegetation. Eight Realms were distinguished. The second division is the Biome. These were not the same as the major vegetation formations of the world (see UNESCO, 1973), but combine the features of a major vegetation type with climate. There are 14 of these. These were largely based on the work of Dasmann. The third, most detailed, subdivision was the Province, delimited on a faunal, floral and ecological basis. There are 186 of these.

The map is available digitally from WCMC, Cambridge. It is usable at a scale of 1:30,000,000.

The WWF-US terrestrial ecoregions of the world (Dinerstein *et al,*. 1995, Olson *et al,*. 2001)

The purpose of this study was primarily to make a tool for the identification of geographic priorities for biodiversity conservation. The result is a system of regional-scale biogeographic units called ecoregions. These are described as relatively large units of land or water containing a geographically distinct assemblage of natural communities sharing a large majority of their species, dynamics and environmental conditions.

The global coverage was drawn up on a continental basis, and not all parts of the world are currently available. The rationale behind this was that the major split in the global map would be by biogeographic realm. However, the splits were made on political bases, not phylogenetic. Despite this the authors found the division practical for the conservation analyses for which the maps were intended.

The methodology for making the maps included collaboration with regional experts as well as the use of a great number of previously published national and regional maps, including some from Holdridge and McKinnon's Indomalayan Realm study. Udvardy's map was apparently not used.

The primary subdivision within each geographical region (continent) was into six mainly formation-based categories called Major Ecosystem Types, which were then subdivided into 14 Major Habitat Types, which are comparable to the concept of Biome, as used by Udvardy. These were further classified according to Bioregions. There were 867 units of the final class, Ecoregion, identified.

For copies of these maps, in paper or in digital form, please contact WWF-US Conservation Science Program, World Wildlife Fund, 1250 24th Street, NW, Washington DC, 20037-1175, USA.

Maps of the natural vegetation of different regions/continents of the globe

In addition to the above global classification systems, there are a number of regional systems available. Below are a few of the more important regional maps.

BOHN, U. and G.D. KATENINA (1994). *Map of Natural Vegetation.* Komarov Botanical Institute, St Petersburg. Scale 1:2,500,000. This has recently been used as a base map for the delineation of European ecoregions in the WWF-US system of ecoregion classification.

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Annex II

The FAO global ecological zoning framework

Level 1 **Domain**	**Level 2** **Global ecological zone**		
Name	**Name**[18]	**Code**	**Criteria**[19]
Tropical All months without frost, in marine areas over 18°C	rain forest	TAr	wet: 0-3 months dry[20]
	moist deciduous forest	TAwa	wet/dry: 3-5 months dry
	dry forest	TAwb	dry/wet: 5-8 months dry
	shrubland	TBSh	semi-arid: evaporation > precipitation
	desert	TBWh	arid: all months dry
	mountain systems	TM	approximately: > 1000m altitude (sizeable local variations)
Subtropical >7 months over 10°C	humid forest	SCf	humid: no dry season
	dry forest	SCs	seasonally dry: winter rains, dry summer
	steppe	SBSh	semi-arid: evaporation > precipitation
	desert	SBWh	arid: all months dry
	mountain systems	SM	approximately: > 800-1000m altitude (sizeable local variations)
Temperate 4-8 months over 10°C	oceanic forest	TeDo	oceanic climate: coldest month > 0°C
	continental forest	TeDc	continental climate: coldest month < 0°C
	steppe	TeBSk	semi-arid: evaporation > precipitation
	desert	TeBWk	arid: all months dry
	mountain systems	TM	approximately: > 800m altitude (sizeable local variations)
Boreal <4 months over 10°C	coniferous forest	Ba	vegetation physiognomy: coniferous dense forest dominant
	tundra woodland	Bb	vegetation physiognomy: open woodland and sparse forest dominant
	mountain systems	BM	approximately: > 600m altitude (sizeable local variations)
Polar	polar	P	same as domain level: all months < 10°C

[18] Reflecting dominant zonal vegetation, resulting from macroclimatic gradients.
[19] Approximate equivalent of Köppen-Trewartha hectare climatic types, in combination with vegetation physiognomy and one orographic zone within each domain.
[20] A dry month is defined as the month in which the total precipitation expressed in millimeters is equal to or less than twice the mean temperature in degrees centigrade.

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