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SPATIALIZED PRODUCTION MODELS FOR SUSTAINABLE PALM OIL IN CENTRAL AFRICA: CHOICES AND POTENTIALS

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Abstract

The communication presents an analysis of lands potentially favorable to the production of sustainable palm oil in accordance with the Roundtable on Sustainable Palm Oil (RSPO) principles and criteria, in 5 countries: Cameroon, Gabon, Republic of Congo, Democratic Republic of Congo and Central African Republic. A spatial modeling exercise locates the areas (I) suitable to oil palm, (II) available after taking into account the RSPO social and environmental constraints, (III) profitable according to various production models. The two production models tested consist of an industry associated with out-growers, and smallholders' plantations associated with family extraction and micro oil mills. The smallholders model was declined in two scenarios, the first regarding as available only lands currently not-cultivated, the second authorizing the plantation of palm trees on lands used for commercial crops at a minimal distance of 2 km of villages (reserved for food-crops). The maps generated are useful decision-making tools.

Key Words: Family Farming, Industry-Smallholders Partnership, Forest Conservation, Land Use Planning, Spatial Modelling, oil palm plantations.

INTRODUCTION

In Central Africa palm oil production is dominated by small-scale agriculture and artisanal milling. Industrial production is also present, but with a majority of old and neglected plantations. In the region, the domestic demand for oils keeps growing, following the international trend. As a result all the countries are importing crude palm oil, most often from Indonesia or Malaysia, to cover the demand for food use and transformation industries (soap, refined oil). In consequence the governments want to increase their national production.

The palm oil regional program of the Worldwide Fund for Nature (WWF) in the Congo basin aims at the reduction of the ecological footprint of the palm oil sector, while the livelihoods of local populations are improved. The WWF uses "go and no-go zone" maps as tools to help governments make responsible decisions related to land allocation for agriculture. WWF asked CIRAD for the realization of maps to localize lands potentially favorable to the production of sustainable palm oil in accordance with the Roundtable on Sustainable Palm Oil (RSPO) principles and criteria, in 5 countries: Cameroon, Gabon, Republic of Congo (RC), Democratic Republic of Congo (DRC) and Central African Republic (CAR). The consideration of the geographical constraints induced by the respect of RSPO criteria aims to allow a sustainable development of the palm oil sector, limiting deforestation and greenhouse gas (GHG) emission generated by this sector and protecting biodiversity (environment safeguard), promoting win-win partnerships between smallholders and agro-industries and thus taking part in the alleviation of rural poverty (social and economic safeguard).

METHOD

The CIRAD used a method of spatial modeling to locate the areas (I) suitable to oil palm, (II) available after taking into account the RSPO social and environmental constraints, (III) profitable according to various production models. The two production models tested consist of an industry associated with out-growers (scenario 1), and smallholders' plantations associated with family extraction and micro oil mills (scenarios 2 and 3). The smallholders model was declined in two scenarios, the first regarding as available only lands currently not-cultivated, the second authorizing the plantation of palm trees on lands used for commercial crops at a minimal distance of 2 km of villages (so as to preserve the area of subsistence production of food crops and animal breeding). These production models were designed based on a fine knowledge of the organization of the palm oil sector in the countries targeted by the study.

The approach is geographical and bottom-up. It begins from the producers, with an analysis of their strategies, their knowledges and know-hows and their rights, before working on space and the location of their actions. It is based on the characterization of typical situations for building land-use patterns,

trajectories of change and of sustainable production which are then generalized to national scales (Gazull *et al.* Forthcoming).

Each technical scenario will combine:

- One or several types of producers in association;
- A set of sustainable production norms (national interpretation of RSPO principles and criteria);
- A localized space available to producers to begin or expand the crop;
- A technical model of production.

Each scenario can be summed up to a technical model of sustainable production, which producers can implement in locations determined by their access rights and their human and technical capacities. Potentials are established through a hierarchical and sequential process in three steps:

1. The **theoretical potential**, or soil-climatic potential. It consists in the whole of lands on which climatic, topographic and pedologic conditions are naturally suitable to the studied crop, here oil palm. It represents a biophysical maximum of production with the present cultivated varieties. The qualifying term 'theoretical' is used to underline that this potential does not take into account neither current land uses, nor present and future users. The potential yields of oil palm fresh fruit bunches (FFB) indicated in this paper should be understood as the results of conventional technical cropping practices, using the required fertilization to maximize the production without losses (fertilization based on leaf-diagnosis to estimate the plant needs and deficiencies, and applied carefully to avoid losses through rain wash).

   To calculate the theoretical potential we considered that: the cultivation of oil palm is too risky below an annual rainfall of 1200 mm and above 3500 mm. Oil palm productivity linearly increases with average annual rainfall in the range 1200 mm - 1800 mm: theoretical yields grow from 12 T FFB /ha.year to an optimum 25 T FFB/ha.year. The annual productivity of oil palm is optimal (25 T FFB/ha.year) from 1800 mm to 3500 mm. Furthermore, we also considered, in agreement with the literature, that palm cultivation is too risky in areas with more than three successive dry months (rainfall <50 mm). We considered that the slopes above 12% are not suitable for oil palm cultivation because they require levelling work to prevent landslides and soil erosion risks. Oil palm is a very flexible plant in terms of soil fertility and characteristics (Jacquemard, 2011). It adapts to many types of soil, as long as the general physical characteristics are not extreme. The most common soils of Central Africa have been classified according to their level of suitability for oil palm. Every suitability level is a potential loss of yield relative to the theoretical level given by the rainfall (Ochs, 1977). The theoretical potential has been estimated

by using spatial combination of the different layers of information listed above. For mapping, yields were grouped into 5 theoretical potential classes: null, marginal, moderate, good, and high.

2. The **available potential** covers lands within the theoretical potential that meet the availability requirements. The estimate of this potential therefore takes account of: i) the locations that future users can appropriate under the rules of customary rights and positive law; ii) sustainability standards (RSPO principles and criteria in the case of oil palm, see RSPO 2013); and iii) the ongoing use of these spaces. This potential is similar to most technical potential calculated in the literature, and reports an explicit consideration of future uses and sustainability standards. To meet the RSPO Principles and Criteria (P & C), are excluded from the available lands : statutory protected areas and nature reserves, existing forests (including planted forest), particularly riparian forests, land within 100 meters of a watercourse to prevent pollution and preserve buffer zones, poor soils and areas of steep slopes (> 12%). Moreover, according to the principle 7.5 of the RSPO, industrial plantations must also preserve current local land uses such as hunting, fuelwood and non-timber forest products collection, and family farming (food crops). Thus a buffer of not-available land will be established around the villages and roads.
3. The **technical potential** for production is a fraction of the available potential that actors can develop following agronomic models that they are technically able to implement. This potential is based on an analysis of local production conditions such as: i) infrastructure, that defines the radius of mills supply basins, ii) potential attainable yields that define minimal surfaces plantation needed to supply the raw material to a mill and thus indirectly define the accurate mill capacity. The identification of the lands in conformity with the technical model is made through a succession of focal analysis in raster mode. 3 scenarios have been developed based on the technical model:
    a. Scenario 1: the first production model chosen in this study is based on an agro-industrial plantation and mill complemented by associated village plantations, a common model in Indonesia and Malaysia (Feintrenie et al 2010), and also true to Colombian alliances models. Industrial units of production and extraction are set up. These mills have a treatment capacity of 300 000 T FFB / year, which corresponds to an hourly capacity of 75 T FFB, tantamount to two mills of intermediate size between the eldest and newest existing factories in the region. The supply basin for this mill capacity covers a 15 000 ha plantation for an average annual yield of 20 T FFB/ ha.year. These extraction units are fueled in part by a set of new plantations, industrial - business ownership - and partly by new nearby village plantations. All these plantations will be located in a maximum radius

of 30 km in order to limit transport costs and loss of quality of the raw material (oil palm fruit oxidize rapidly after the harvest which makes the extracted oil more acid). The industrial plantations are large mechanized plantations and can be partially fragmented into lots of 100 ha minimum. In every 100 ha 5% of land unavailable for whatever reason is tolerated. Village plantation plots are united in production lots of 20 ha which can be divided between several smallholders. This 20 ha size of lots facilitates a possible collection by the industrial partner. The plots will be planted at more than 5 km from the villages and more than 2 km from roads to meet the current and future land uses, especially hunting, firewood collection and food crops (in compliance with RSPO criteria).

b. Scenario 2: The second model is a model involving only village plantations and micro-mill extraction units with a capacity of 4000 T FFB/year. This extraction capacity corresponds to modern micro-mills such as some cooperatives of smallholders currently develop in Cameroon, and to twice the capacity of each extraction unit set up in 2015 by Eco-Oil Energie in RC to process the FFB from its old plantations pending the renewal of these plantations. These extraction units will be supplied by neighboring village plantations. All these plantations will be located in a radius of 15 km maximum in order to limit transport costs and loss of raw material. Village plantation plots shall be at least of 1 ha. The plots will be planted at more than 2 km from the village and from roads to preserve existing food crops.

c. Scenario 3: The third model is similar to Scenario 2 with the difference that conversion of areas currently valued in cash crops to oil palm is allowed (scenario of replanting of existing village plantations). As there is no mapping areas dedicated to cash crops in the 5 countries, it is assumed that all land under cultivation at over 2 km of villages or roads (traditionally reserved for food crop) include mainly cash crops. Thus Scenario 3 corresponds to scenario 2 where the cultivated areas at a distance above 2 km from villages and roads are considered as available.

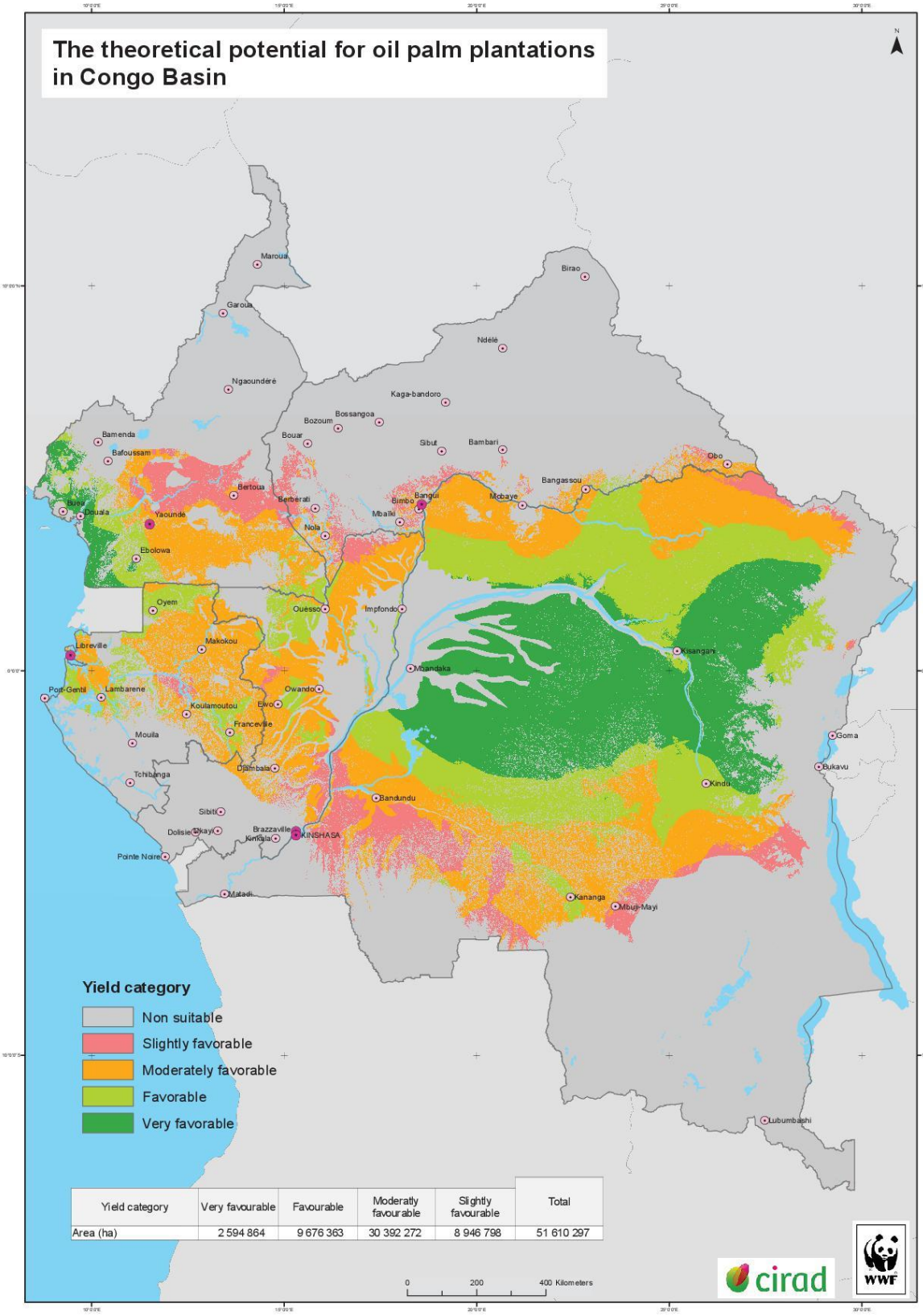
RESULTS

Palm oil production models worldwide are numerous and various: from large-scale intensive agro-industrial units with industrial plantation and mill, through partnerships between an industrial mill and out-growers of small and medium scale, to family farming producers with artisanal mills or oil extraction by hand. An increase in the production undoubtedly passes by the association of these various models.

The average annual rainfall in the entire basin (source WorldClim) only limits the possibilities in northern Cameroon, northern CAR, Southeastern DRC and in the area of Pointe Noire (Republic of Congo). The number of consecutive months of drought limits the possibilities for planting in southern Gabon, Republic of Congo and DRC, as well as in north Cameroon and most of the CAR. Temperatures constraints are mainly expressed through sensitivity to cold (minimum temperatures below 18°C). This is a limiting factor in the majority of CAR, in southern DRC, on the plateaus of the Republic of Congo and Gabon and in the North Cameroon. Most soils of Central Africa are suitable for oil palm cultivation, with varying ability levels. Unfit soils are mainly hydromorphic soils in the river Congo Basin, and some soils of southern CAR. As a result of these soil and climatic factors and the requirements of oil palm, the theoretical potential for oil palm plantations is spread over more than 51 million hectares across the 5 countries, including 2.5 million ha very favorable to the crop (Figure 1).

The most favorable area in Cameroon is the historical oil palm belt where the first industrial plantations have been developed (Nkongho et al. 2015). In DRC as well, the first industrial plantations were established at the beginning of the XXth century (in the 1910 to 1919 decade) in areas with good and high yield potential (AGRER -Earth Gedif 2005). Oil palm development is more recent in the other countries with a lower yield potential: 1960s in RC, 1980s in Gabon and CAR (Feintrenie 2014).

These areas of historical oil palm development have often witnessed local economic development with an increase in population density, road network density and conversion of forest cover to other land uses such as agriculture (both food crops and cash crops), urbanization, industry or protected areas. This is translated in social and environmental constraints to develop new oil palm plantations that respect RSPO P&C. National maps of these constraints are presented in Gazull et al. (2015) report. The example of Cameroon (Figure 2) illustrates the high density of social and environmental constraints that exclude any possibility of development for new industrial plantation sin the most favorable areas. As a consequence, the available potential for sustainable oil palm plantations is mainly spread among areas presenting only marginal or moderate yield potential (Figure 3). Some patches of available potentials in areas of good or high yield potential are visible when zooming on the maps.



Yield category	Very favourable	Favourable	Moderatly favourable	Slightly favourable	Total
Area (ha)	2 594 864	9 676 363	30 392 272	8 946 798	51 610 297

Figure 1: Theoretical potential for oil palm plantations in the 5 countries of the Congo Basin

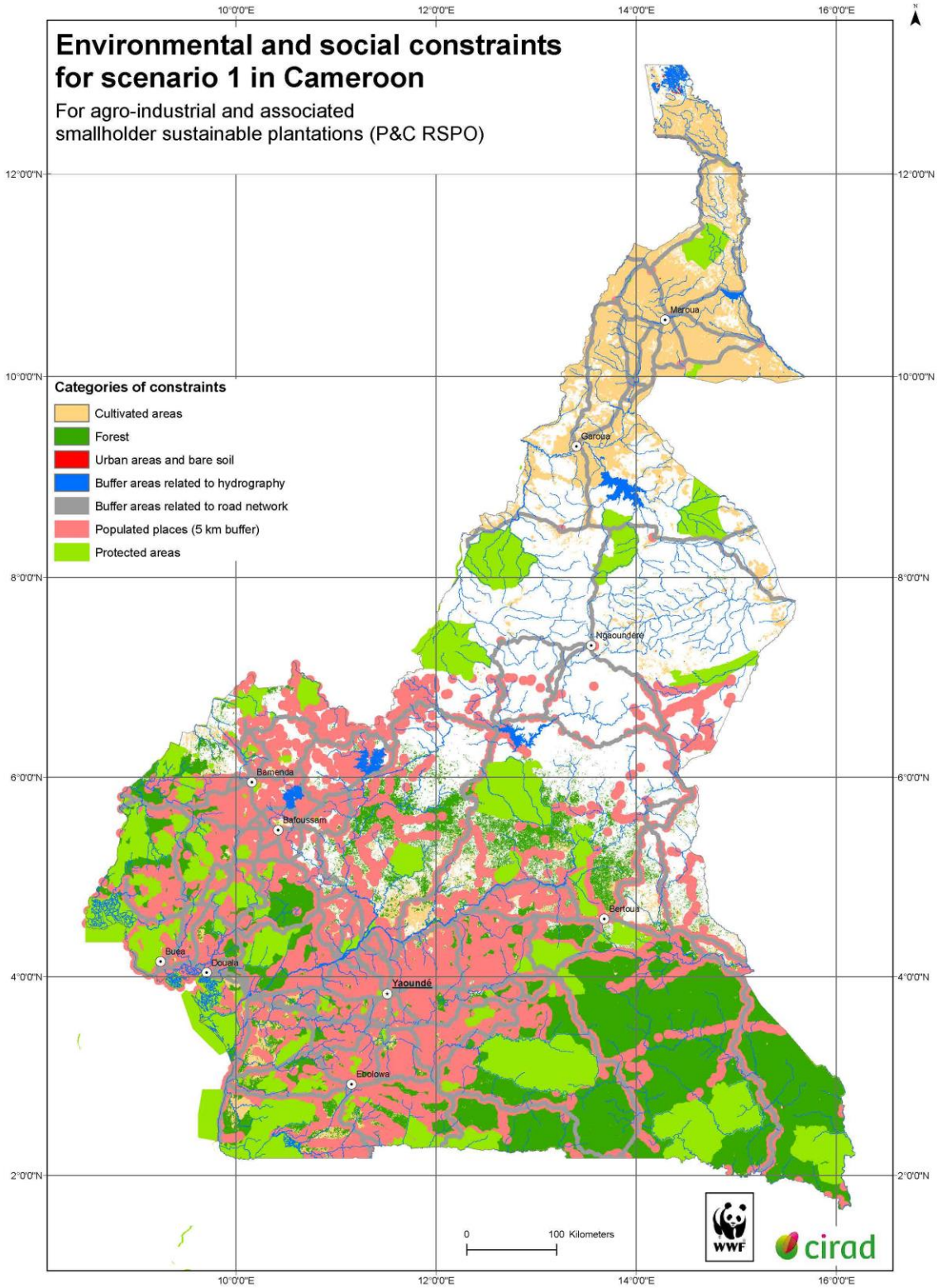


Figure 2: Social and environmental constraints to the development of new industrial plantations in Cameroon

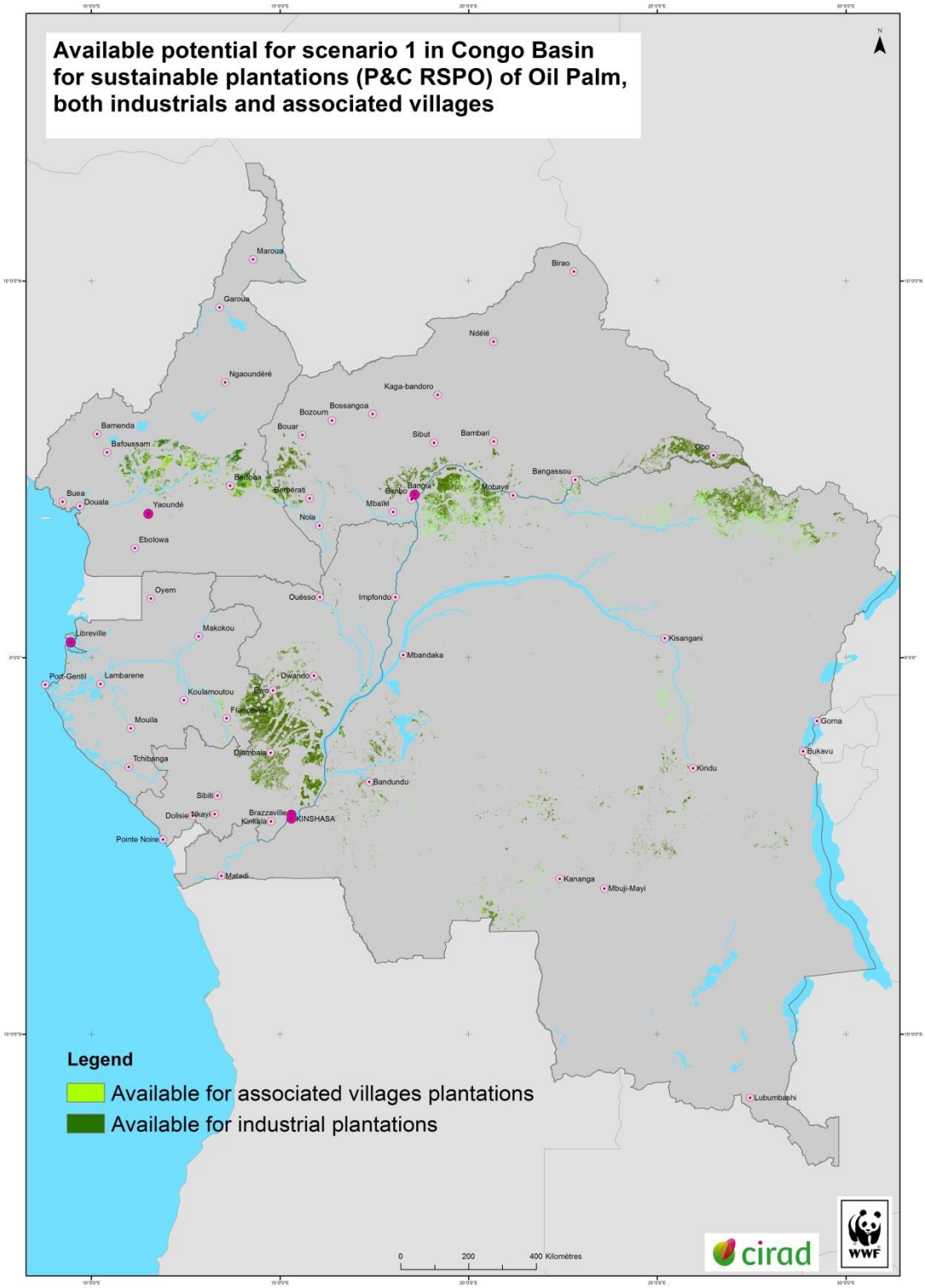


Figure 3: Available potential for oil palm plantations in the 5 countries of the Congo Basin

Figures 4, 5 and 6 summarize, respectively for scenarios 1, 2 and 3, the potentials in each country per yield class. The theoretical potential includes the available potential which includes the technical potential. Differences are small between available and technical potentials and thus the available potential does not appear much on the figures 4 to 6. The available potential for village plantations associated to family oil production and micro-mills (scenario 2, Figure 5) is higher than the one for new industrial plantations (Figure 4). This is due to the smaller size of continuous land needed for a smallholder's plantation (minimum of 1 ha/plot) in comparison with industrial one (minimum of 100 ha/plot), and to the smaller required distance from villages (2 km for smallholders' plantations against 5 km for industrial plantations).

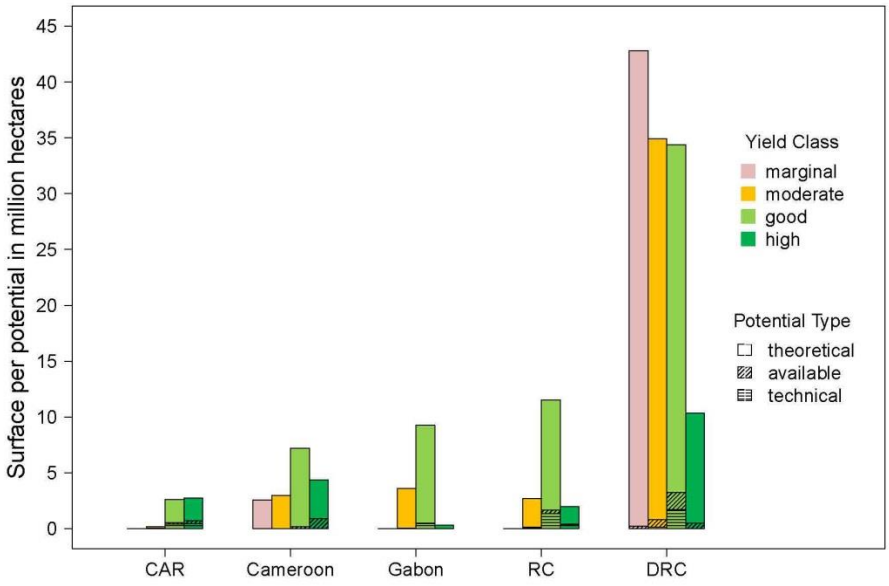


Figure 4: Surface area per potential (ha) for the industrial and associated village plantations model

This difference between scenarios regarding the available potential is exacerbated – in particular in DRC and Cameroon - with the scenario 3 (Figure 6), in which village plantations are allowed on land formerly occupied by commercial crops at a distance higher than 2 km from villages and roads. This scenario would apply for example when a producer decides to change a cocoa, rubber or pineapple plantation into an oil palm plantation, or to replace an old and unproductive oil palm plantation by a new one.

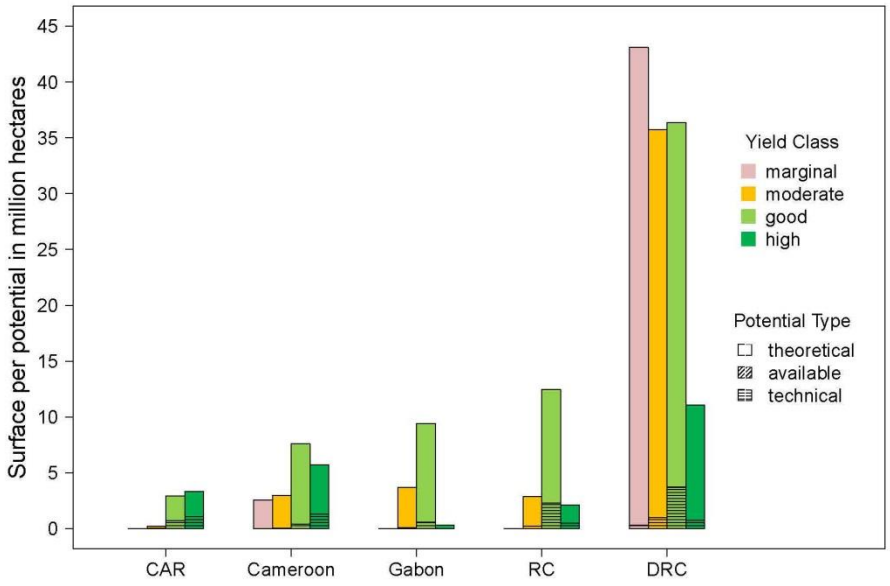


Figure 5: Surface area per potential (ha) for the village plantations associated with micro-mills model

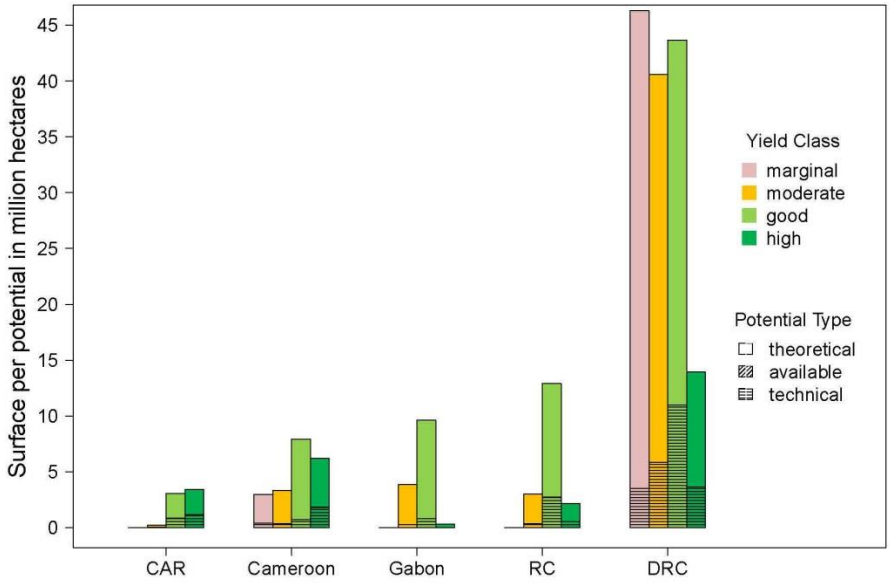
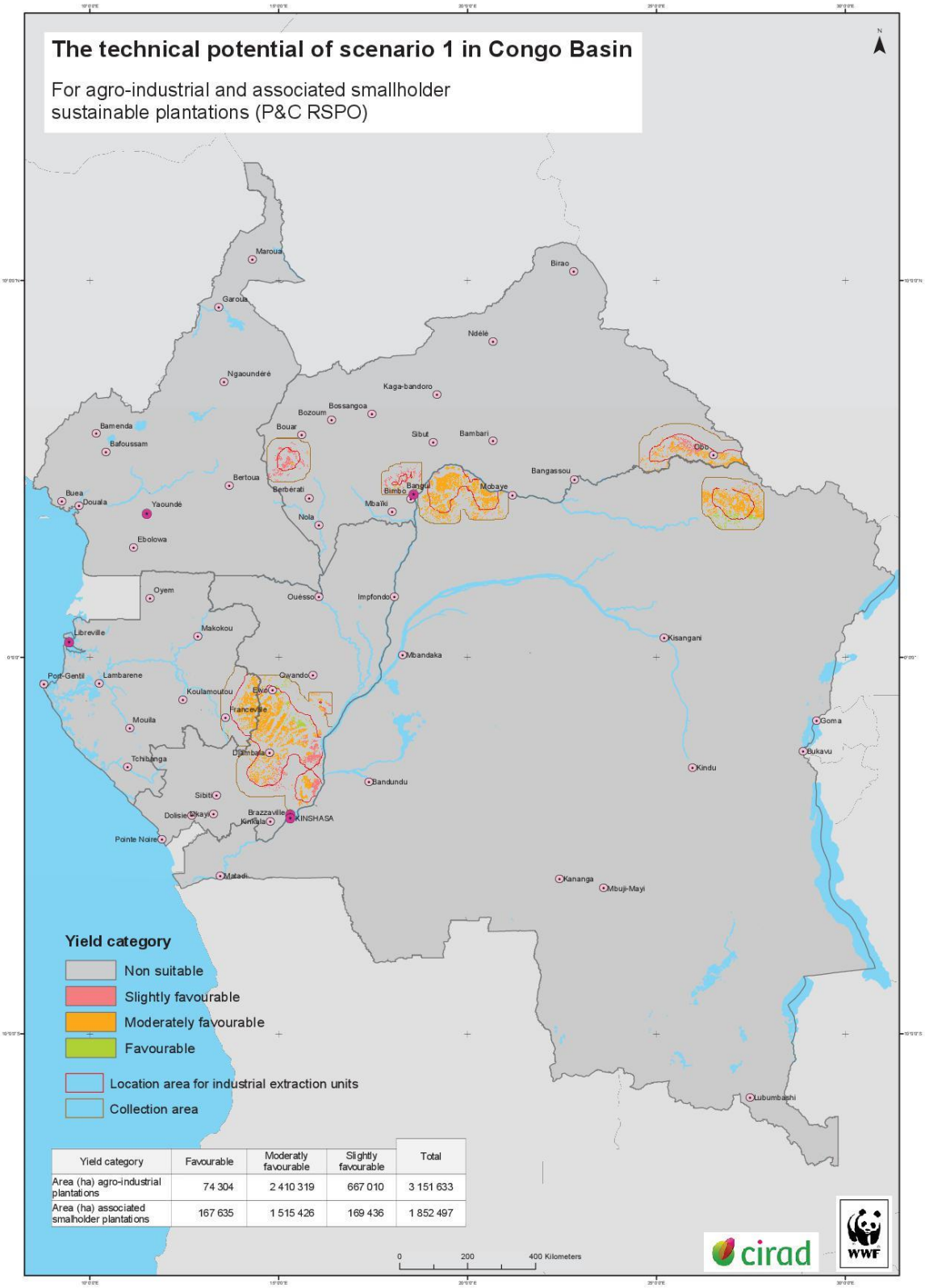


Figure 6: Surface area per potential (ha) for the village plantations associated with micro-mills and allowing commercial crops replacement model



Yield category	Favourable	Moderatly favourable	Slightly favourable	Total
Area (ha) agro-industrial plantations	74 304	2 410 319	667 010	3 151 633
Area (ha) associated smalholder plantations	167 635	1 515 426	169 436	1 852 497

Figure 7: Technical potential for industrial plantations in association with village plantations, scenario 1, in the 5 countries of the Congo Basin

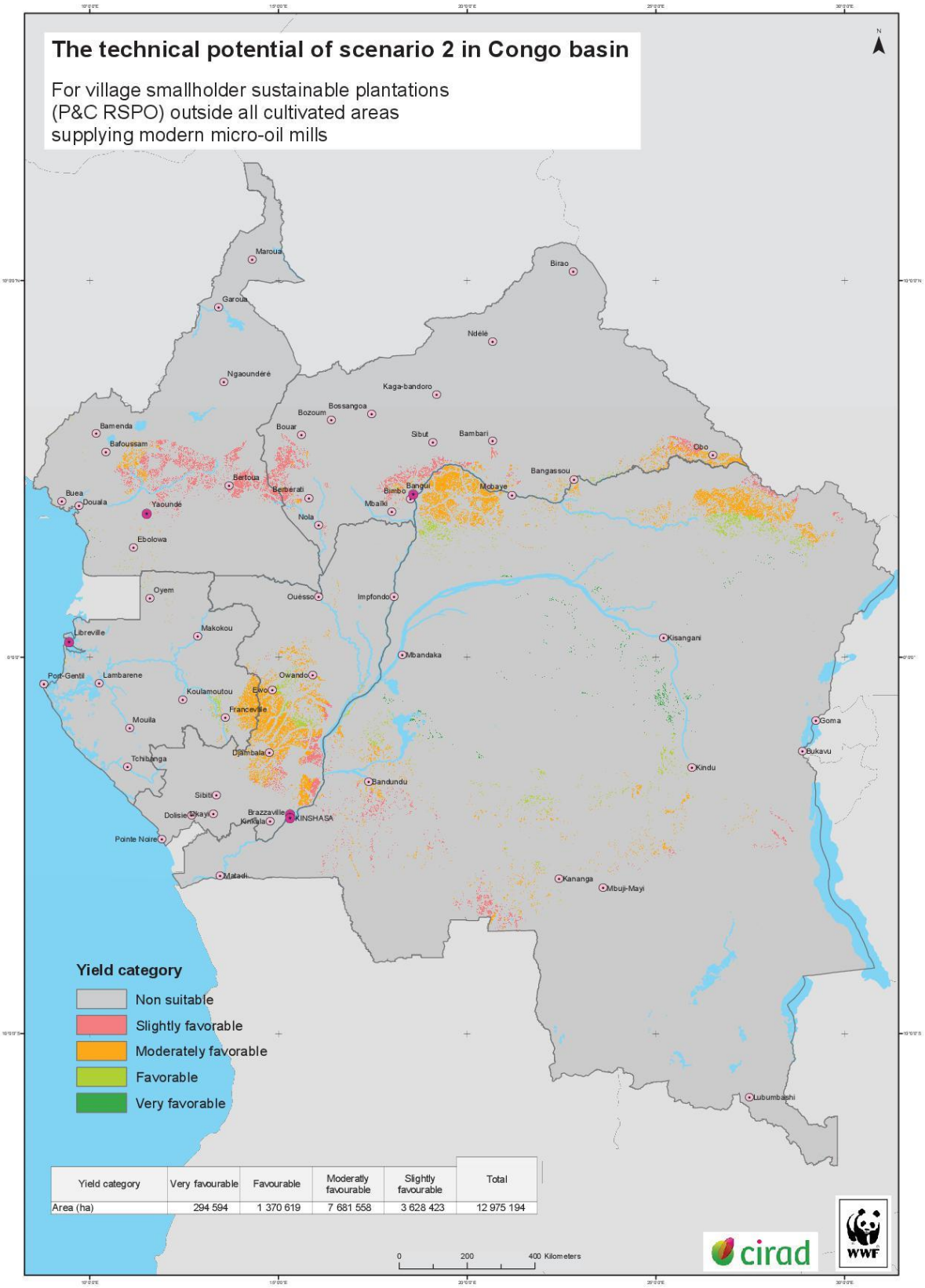
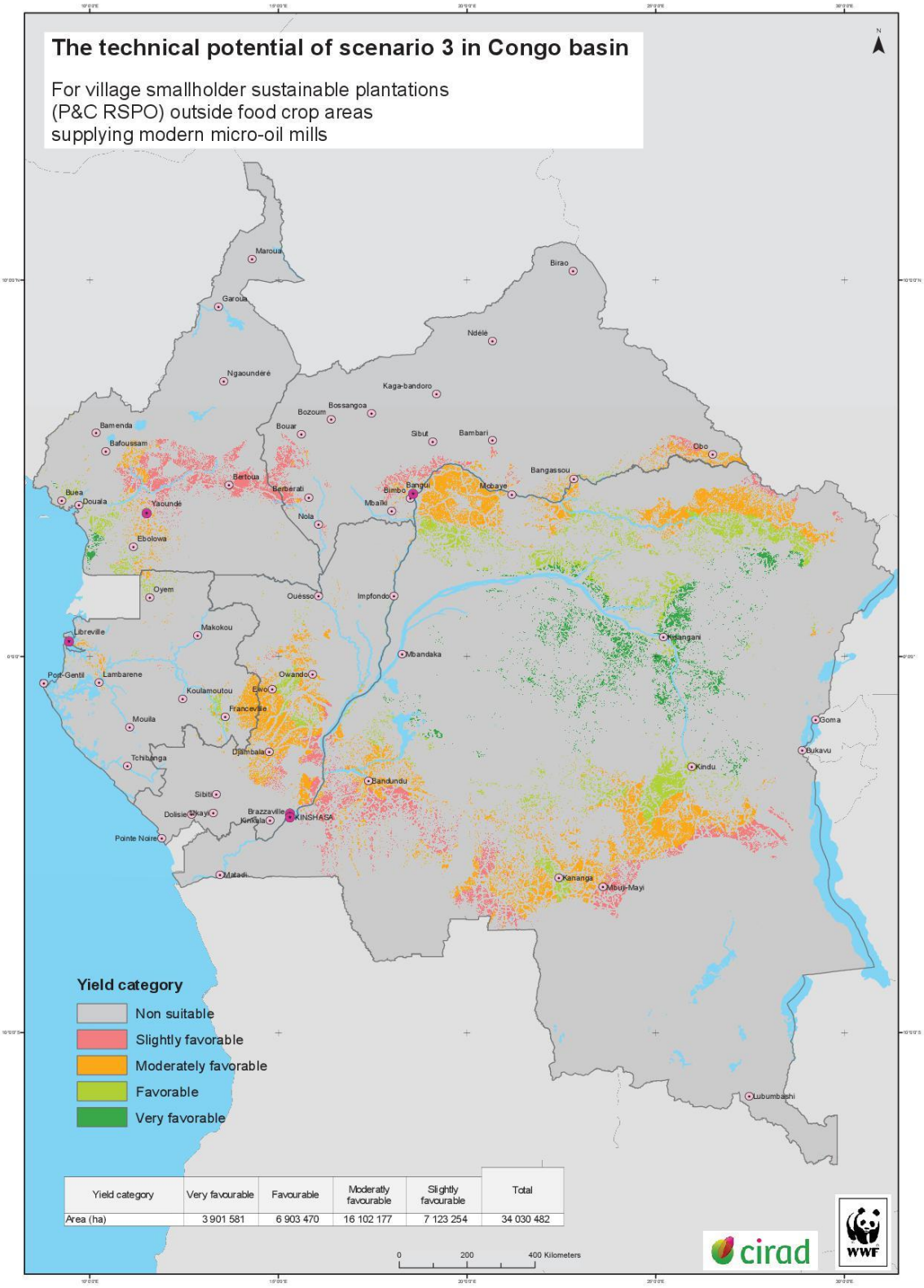


Figure 8: Technical potential for village plantations, scenario 2, in the 5 countries of the Congo Basin



Yield category	Very favourable	Favourable	Moderatly favourable	Slightly favourable	Total
Area (ha)	3 901 581	6 903 470	16 102 177	7 123 254	34 030 482

Figure 9: Technical potential for village plantations, scenario 3, allowing plantations on areas cultivated in cash crops but preserving subsistence crop cultivated areas, in the 5 countries of the Congo Basin

The maps of technical potential for scenarios 1 (Figure 7), 2 (Figure 8) and 3 (Figure 9), illustrate that every production model is not adapted to every context. The country ecological and human specificities had to be taken into account in the choice of one or the other. The results of the spatial modelling exercise show important differences between the countries of the Congo basin.

In Cameroon, most of the area suitable to oil palm is already occupied by villages and urban areas, industrial plantations (of oil palm, rubber, banana, sugar cane) and protected areas. There is no space left for new industrial oil palm plantations (Figure 7), and few for new smallholders' plantations (Figure 8). There, priority should be given to replanting of old and slightly producing plantations (Figure 9), both industrial and smallholdings.

In Gabon land occupancy by protected areas and natural forests of high conservation value is a major constraint to further industrial oil palm plantations. Some areas suitable and potentially profitable for both industrial and smallholding models can be found mainly in Haut-Ogooué province. Some industrial plantations are currently under development in the river Ngounié valley (including Mouila city), which appears with a null yield potential in this model (Figure 1) due to 4 consecutive dry months. This might be explained either by a micro-climate not embraced by the data used in the modelling, or by accessible underground water reserves that compensate the lack of rain. In both case however, this area is not the most favorable location to produce oil palm fruits.

In Republic of Congo the central part of the country offers good potential for development of both industrial and small-scale plantations. Industrial mills should be chosen with medium transformation capacity (around 20 t Fresh Fruit Bunches/hour) to be adapted to the low yield potential of suitable and available lands. A well-spread sector with small-scale transformation units would be better adapted to the country potential than large mills, and have a larger social and economic development impact. *(Feintrenie et al. 2014a)*

In Democratic Republic of Congo the yield potential is the highest of the region (yield class very high), up to 25 t FFB/ha for industries or 20 t FFB/ha for smallholdings. The social and environmental constraints of RSPO restrict the possibilities of oil palm development, especially for industrial production models. The potential for small scale production models is very high, and should be considered with and without partnerships with industries.

In Republic of Central Africa lands suitable for oil palm are limited to the southern part of the country, with a low yield potential (mainly due to climatic factors). Most of this area is already occupied by villages and cultivated areas and some protected areas. In consequence there is no land left for new industrial plantations. Smallholdings associated with micro oil mills could nevertheless be developed, but with low yield expectations.

DISCUSSION

In our approach, the availability of land for new plantations is expressed in relation to the future producers in a given territory. In addition to taking into account stakeholders, the originality of this method resides in the spatial modelling of sustainability criteria and future production systems. Compared to other assessment methodologies, our approach expresses explicitly the RSPO criteria and tries to translate them into spatial constraints. Unfortunately this spatial modelling cannot take into account all the social and environmental rules that define RSPO but the major principles that could have impacts on land are considered.

Likewise, the analysis of producers' know-how and constraints allows spatial models of future production systems to be built which, when confronted with land use maps and RSPO spatial constraints, allows the identification of land which is technically suitable to host such systems.

This spatial approach combining expert knowledge with geographic data bases is certainly one of the best way to produce maps useful for land-use planning (George & Petri, 2006). But results are highly sensitive to knowledge of land cover, in particular: cultivated areas, transportation infrastructures, and settlements. This work shows this kind of information is not of equal quality in all countries of the region. In particular, more accurate data is needed in DRC about the road network and existing settlements. This approach via the different possible stakeholders, even generalized, allows also a discussion of potential complementarity or competition between different production modes.

The maps resulting from this study will be proposed as support for decision-making regarding land-use planning, and regarding large-scale land allocation for agro-industrial investments in the five studied countries.

This tool is crucial to help governments to make responsible decisions about national and regional land use planning and will be used as inputs for the development of the regional sustainable palm oil strategy that WWF and ECCAS (Economic Community of Central Africa States) committed to design for in 2016. The WWF will now disseminate the "go and no go zone" maps and promote their endorsement by decision makers and their integration into national and regional land uses policies and land allocation strategies. The final objective is to achieve development and l implementation of regional l sustainable

palm oil strategies including the "go and no go zone" maps in the 10 ECCAS country members. That regional sustainable palm oil strategy will drive sustainable palm oil production and consumption in Central Africa.

CONCLUSION

Central Africa presents a true potential for oil palm development. This potential is different in each country of the region, due to their ecologic, social, economic and historical characteristics. The spatial modeling allows testing various production models and underlines their possible extension and spatial limits. The maps produced are useful tools for decision-making both for private investors and political land use planning.

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