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Charcoal, Forests and Livelihoods in the Northern Cardamoms, Cambodia

Participatory impact assessment of Charcoal production using Global Forest Watch

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Global Forest Watch (GFW) is a dynamic online forest monitoring and alert system that empowers people everywhere to better manage forests. For the first time, Global Forest Watch unites satellite technology, open data, and crowdsourcing to guarantee access to timely and reliable information on forests. GFW is free and follows an open data approach in putting decision-relevant information in the hands of governments, companies, NGOs, and the public.

Website: http://www.globalforestwatch.org/

This project has been implemented by **GERES** and **Mlup Baitong**

Group for the Environment, Renewable Energy and Solidarity (GERES) is a French non-profit NGO created in 1976 after the first oil crisis. Environmental conservation, climate change mitigation and adaptation, reducing energy poverty, and improving livelihoods of the poor are the main focus areas for GERES. The GERES team is particularly involved in the implementation, in partnership with local stakeholders and communities, of engineering solutions for development and providing specific technical expertise.

Website: http://www.geres.eu/en/

Mlup Baitong is a Cambodian NGO working to increase environmental awareness and conservation, seeking solutions for sustainable and equitable use of natural resources through education, training and advocacy, and community-based natural resource management and eco-tourism activities. Mlup Baitong's goal is to contribute to poverty alleviation in Cambodia through right based empowerment of rural communities to manage their natural resources sustainably while obtaining improved livelihoods.

Website: http://www.mlup-baitong.org/

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SUMMARY

1 INTRODUCTION

Located in the centre of the fast growing South-East Asian region, Cambodia is changing quickly but with rapid growth also comes increasing social inequalities. Cambodia is one of the poorest countries in South-East Asia with 17.7% of its population living under the poverty line[1]. Total forest area in Cambodia is estimated at 10,864,186 ha by the FAO, equivalent to approximately 56% of its total land area[2]. Nevertheless, forests have suffered from both deforestation and land degradation since the 1960s, mostly due to the illegal timber trade and large-scale agricultural projects which have strongly accelerated during the last decade. Cambodia is also the world's 12th most vulnerable country to the effects of climate change according to the MapleCroft 2015 report[3]. Cambodia's rural households account for 80% of the total population. These rural areas strongly rely on forest resources to sustain their livelihoods (e.g. charcoal, rattan, mushroom and other NFTPs which contribute about 30 to 42% of total household income[4]). Depletion of forest resources combined with low resilience to climate change is expected to have a significant effect on the livelihoods of a majority of the Cambodian population.

Since the 1970s, worldwide charcoal production has been beset by misconceptions, based on a lack of reliable information. This lack of accurate knowledge on the realities of charcoal production has led to the marginalization of charcoal producers and often inadequate policies, in Cambodia as well as across the world[5], to govern the charcoal sector and tackle the current "Tragedy of the commons"[6].

"The production, use and trade of charcoal for domestic cooking and heating are characterized by contradictions, stereotyping, and misconceptions. Partial information, over-generalizations, and the tendency to consolidate charcoal with other biomass fuels have contributed to gross misrepresentation of charcoal in terms of its actual impact on forests, its role in improving energy access, and inappropriate interventions." [7]

Figure 1 – Informal charcoal production centre in Phnom Aural - Kampong Speu province, Cambodia (GERES)

In Cambodia, biomass energy accounts for more than 71% of the energy mix[8] which is the highest proportion in South-East Asia. For domestic cooking, 82% of Cambodian households use woodfuels as

[1] World Bank, "World Development Indicators", http://data.worldbank.org/country/cambodia
[2] More information available on the FAO Global Forest Resources Assessment 2010 website: http://www.fao.org/forestry/fra/fra2010/en/
[3] MapleCroft, "Climate Change Vulnerability Index 2015", http://maplecroft.com/themes/cc/
[4] Kasper K. Hansen and Neth Top, "Natural Forest Benefits and Economic Analysis of Natural Forest Conversion in Cambodia, Working Paper 33", CDRI, 2006
[5] J.E. Michael Arnold, Gunnar Köhlin, et Reidar Persson, « Woodfuels, livelihoods, and policy interventions: Changing Perspectives », *World Development* 34, nº 3 (March 2006): 596-611, doi:10.1016/j.worlddev.2005.08.008.
[6] In the "tragedy of the commons" concept, individual charcoal producers' interest to produce a maximum of charcoal results in the destruction of the resource, which supports the livelihood of the entire community
[7] Tuyeni H. Mwampamba et al., « Dispelling common misconceptions to improve attitudes and policy outlook on charcoal in developing countries », *Energy for Sustainable Development* 17, nº 2 (2013): 75-85.
[8] International Energy Agency, "Statistics – Cambodia Balance", www.iea.org/statistics/statisticssearch/report/

their main fuel; 18% of which use charcoal as their primary fuel[9]. Cambodia's total energy consumption is projected to grow at an average annual rate of 5.2% from 2009 to 2035[10], and charcoal is expected to continue to represent an important part of the energy mix.

While in urban areas the consumption of charcoal is expected to slightly decrease[11], it is expected to increase by 53% in rural areas between 2012 and 2030[12]. At the national and regional levels, charcoal consumption is expected to rise until 2030 at least[13].

Therefore, woodfuels, and more specifically charcoal, represent a highly strategic economic sector for Cambodia, as stated in the National Energy Efficiency Policy formulated by the Ministry of Mines and Energy (MME)[14].

However, international and national investments in the sector remain low. One of the reasons could be that charcoal is considered as energy for the poor, to be replaced by LPG (Liquid Petroleum Gas) and/or electricity. This vision has been popularized by Leach[15] in the 1990s with the "energy ladder" concept, where households adopt progressively more modern energy sources and reduce traditional wood fuel use as they become wealthier and as cleaner sources of energy become more accessible.

However, recent studies suggest that charcoal is not energy for the poor as it is predominately used in urban areas where higher levels of income are observed[16]. A survey conducted by GERES in 2013 on 1,969 households[17], representative of the Cambodian population, shows that the share of households that use charcoal as a primary fuel does not decrease with an increase in wealth (Figure 2). This fact is also observed in Phnom Penh, where LPG is most widely available, and is in line with observations made in other developing countries[18].

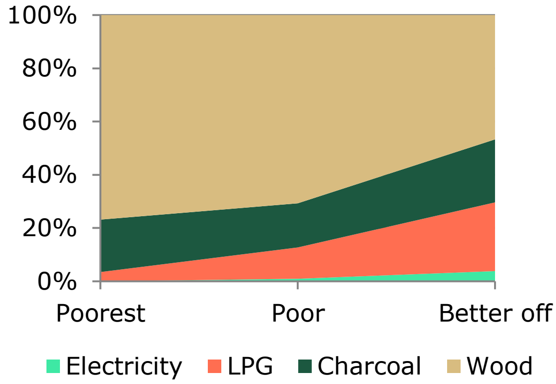


Figure 2 – Main fuel used by households in Cambodia per income category (GERES)

The above statement confirms the modern vision of the energy ladder by Masera *et al*[19] which predicts that instead of switching from wood to charcoal and then from charcoal to LPG or electricity, where income impacts the number of fuels used by the household, charcoal remains a very important fuel. Such results tend to support the projections that no significant reduction in charcoal usage is expected in the near future in the Cambodian domestic cooking energy mix. Charcoal's economic importance has also been widely underestimated by policy makers. GERES estimates that Cambodia's national charcoal

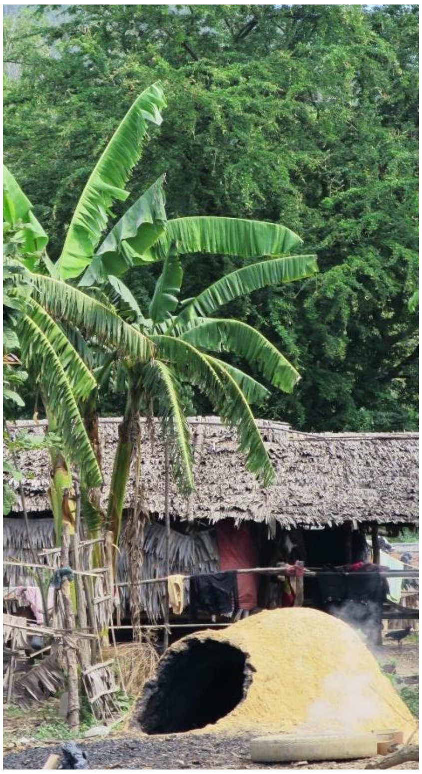
[9] GERES, 2013. Nationwide Domestic Use of Cooking Fuels and Devices. Nation-wide baseline Survey.
[10] Asian Development Bank, « Asian Development Outlook 2013: Asia's Energy Challenge », April 2013, 978-92-9254-023-4.
[11] M. Sarraf et al., « Renewable energy policies for sustainable development in Cambodia », *Renewable and Sustainable Energy Reviews* 22 (2013): 223-29.
[12] GERES, « Residential energy demand in rural Cambodia » (UNDP, 2008).
[13] J.E. Michael Arnold, Gunnar Köhlin, et Reidar Persson, « Woodfuels, livelihoods, and policy interventions: Changing Perspectives », *World Development* 34, nº 3 (March 2006): 596-611, doi:10.1016/j.worlddev.2005.08.008.
[14] Previously Ministry of Industry, Mines and Energy, « National policy, Strategy and Action plan on Energy Efficiency in Cambodia », 2013.
[15] Gerald Leach, « The energy transition », *Energy policy* 20, nº 2 (1992): 116-23.
[16] Tuyeni H. Mwampamba et al., « Dispelling common misconceptions to improve attitudes and policy outlook on charcoal in developing countries », *Energy for Sustainable Development* 17, nº 2 (2013): 75-85.
[17] GERES, 2013. Nationwide Domestic Use of Cooking Fuels and Devices. Nation-wide baseline Survey.
[18] Douglas F. Barnes, Kerry Krutilla, and William F. Hyde, *The urban household energy transition: social and environmental impacts in the developing world.* (Routledge, 2010).
[19] Omar R. Masera, Barbara D. Saatkamp, and Daniel M. Kammen, « From linear fuel switching to multiple cooking strategies: a critique and alternative to the energy ladder model », *World development* 28, nº 12 (2000): 2083-2103.

production was around 336,000 tons in 2013[20]. Considering an average retail price of 0.35 USD per kilogram, the Cambodian charcoal market would represent more than 117 million USD per year, which makes it a significant economic sector for rural Cambodia.

Charcoal production is often described as a significant driver of deforestation, although recent studies show that in tropical countries, charcoal production would represent less than 7% of the total forest cover loss[21]. Debates on charcoal production in Cambodia are often focused on the question "Is charcoal a driver of deforestation?"[22]. In addition to the semantic aspect of this question (deforestation vs. degradation), positions taken by government and civil society are rarely based on evidence. Indeed, despite the importance of charcoal in Cambodia and across developing countries, and the need for information on the local dynamics of charcoal production for policy interventions, few approaches to assess the impact of charcoal production among the other drivers of deforestation have been developed and applied.

Recently, a wide range of scientific research has shown the potential of sound forest management, charcoal kiln improvements and changes in national policies to improve the livelihoods of charcoal producers[23,24,25]. The time has come to forget about the misconceptions and to undertake scientific analysis using sound data and field evidence in order to bring the complex reality of charcoal production dynamics to light. This is the core ambition of this project.

To assess the complex dynamics of charcoal production, the project developed a simple approach replicable by grassroots organizations and based on the use of the intuitive Global Forest Watch platform. By providing reliable information and increasing awareness of policy makers and communities about local issues, such an approach could enable institutional changes towards sustainable management of forest resources and significantly contribute to forest conservation, improved energy security and increased resilience of poor rural communities living at the intersection of forest and agricultural lands.



[20] GERES, 2015. Nation-wide assessment of biomass consumption patterns in Cambodia. To be released soon.
[21] Emmanuel N. Chidumayo and Davison J. Gumbo, « The environmental impacts of charcoal production in tropical ecosystems of the world: a synthesis », *Energy for Sustainable Development* 17, nº 2 (2013): 86‑94.
[22] Example of such debates: http://www.phnompenhpost.com/national/living-dwindling-trade
[23] Leo C. Zulu and Robert B. Richardson, « Charcoal, livelihoods, and poverty reduction: Evidence from sub-Saharan Africa », *Energy for Sustainable Development* 17, nº 2 (2013): 127‑37.
[24] Mwampamba et al., "Dispelling common misconceptions to improve attitudes and policy outlook on charcoal in developing countries."
[25] Jolien Schure et al., « Formalisation of charcoal value chains and livelihood outcomes in Central-and West Africa », *Energy for Sustainable Development* 17, nº 2 (2013): 95-105.

2 MATERIALS AND METHODS

To assess the impact of charcoal production on Cambodian forests, this study follows the main principles of the WISDOM methodology developed by FAO and UNAM[26,27].

It involves a supply-chain analysis to trace back the charcoal from markets to forests where the wood for charcoal is collected. It aims to accurately locate the charcoal production areas and gain an understanding of the interactions with other land uses.

An important part of the land-use data comes from open-data geographical data published by Open Development Cambodia[28]. This type of data is however not mandatory as it could also be obtained through community workshops supported by historical deforestation maps from Global Forest Watch.

Two case studies have been selected in Phnom Aural (Kampong Chhnang and Kampong Speu province) and Koas Krolar (Battambang province). These areas have been selected for the significance of charcoal production and because they present very different land-use change dynamics. The project methodology was implemented as follows:

Step 1. Preliminary data collection: From market to woodsheds

The first step consisted of an assessment of the charcoal flows and production patterns through a snowball approach starting from charcoal markets going up to the distributors and then the charcoal producers. An initial survey, done at the end of 2013 (47 charcoal producers and 66 woodfuel traders surveyed in 6 provinces), highlighted the charcoal production hotspots which led to the selection of the 2 study areas for the project, representing 2 different dynamics. In the selected areas, an in-depth socio-economic survey for charcoal producers was conducted for a more detailed analysis of the charcoal production patterns (48 producers, 1h/interview). In addition to the socio-economic questionnaire, charcoal producers were asked to bring the surveyors on-site in the different locations where they have been collecting wood for the last 10 years. These data were used to determine the location and date of the 24h checkpoints.

Step 2. Quantitative assessment of charcoal extracted through 24h CTV counting

To account for the amount of charcoal leaving the study area over a 24h period, 14 checkpoints were located on Google Earth using the surveyors' feedback. A typology of Charcoal Transportation Vehicle (CTV) with their approximate quantity of charcoal was developed (see annex 1) in order to estimate the quantity of charcoal transiting within 24h. The 24h checkpoints were undertaken in 3 provinces between the 20th and 29th of November 2014. Data was then processed to avoid double counting and extrapolate the November CTV counting to the mean annual production. Seasonality patterns from the socio-economic surveys were used to increase the precision of the extrapolation. Finally, the charcoal demand was converted in wood equivalent by considering a wood-to-charcoal ratio of 6.41[29] and the share of total above ground biomass used for charcoal of 80%.

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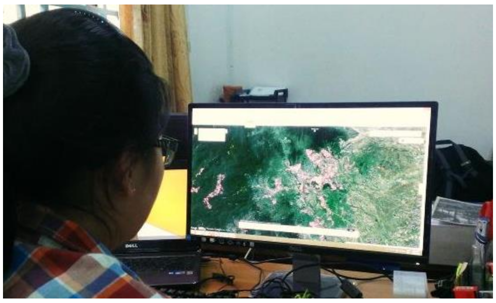
[26] Omar Masera et al., « WISDOM: A GIS-based supply demand mapping tool for woodfuel management », *Biomass and Bioenergy* 30, nº 7 (juillet 2006): 618- 37, doi:10.1016/j.biombioe.2006.01.006.

[27] This methodology has been used very recently to publish a study which provides, according to the Global Alliance for Clean Cookstoves (GACC), one of the funders of this study, "the most advanced data on the climate impacts of wood burning" - http://www.cleancookstoves.org/about/news/01-21-2015-new-study-estimates-that-clean-cookstoves-could-reduce-emissions-from-woodfuels-by-up-to-17-percent.html

[28] http://www.opendevelopmentcambodia.net/

[29] GERES field tests of traditional charcoal kilns efficiency.

Step 3. Assessment of biomass stocks and supply potential



The deforested area in the two study zones was computed using ArcGIS 10.2.2 and the tree cover loss and gain from Hansen[30]. To estimate the stock of biomass, a regression linking the Above Ground Biomass (AGB) stock and forest tree cover was developed. To do so, a set of forest inventories representative of the wood collection areas were collected among GERES, Mlup Baitong and partners. To estimate the biomass supply potential, the AGB was converted in Mean Annual Increment (MAI) by using a regression developed under similar conditions[31].

Step 4. Qualitative assessment and stakeholder analysis through community workshop sessions

To validate the previous findings, two community workshops were organized in Phnom Aural and Koas Krolar. These workshops gathered charcoal producers (both men and women) and village chiefs. The participants were split into two groups and were invited to observe the dynamics of deforestation in their respective areas watching videos captured from the GFW website[32]. Then, they were asked to draw maps of the land use around the village as of 10 years ago by indicating villages, forests and paddy fields. Finally, they had to draw major land cover changes that happened within the last 10 years as shown in the video from GFW. For different periods, they had to indicate where they used to collect wood for charcoal, what were the reasons for the deforestation observed in GFW and the impacts of these changes on their farming activities.

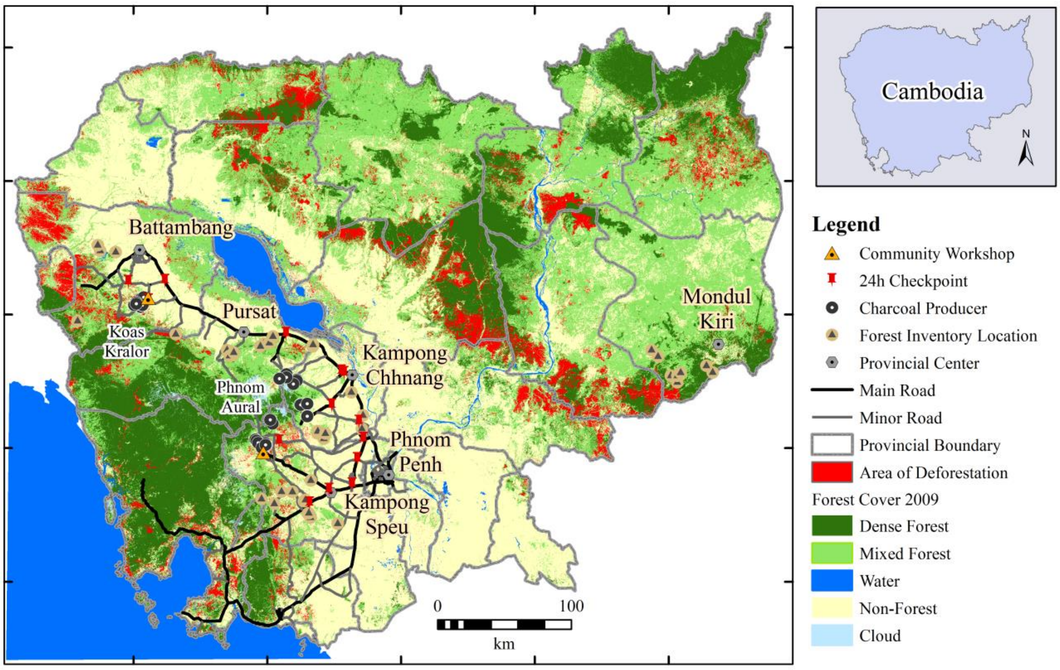


Figure 3 - Localisation of the field activities and study areas

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30 Hansen/UMD/Google/USGS/NASA Tree Cover Loss and Gain Area map

31 Neth Top et al., « Re-assessment of woodfuel supply and demand relationships in Kampong Thom Province, Cambodia », *Biomass and Bioenergy* 30, nº 2 (February 2006): 134-43, doi:10.1016/j.biombioe.2005.11.008.

32 It important to notice that although GFW is a powerful tool to watch forest cover dynamics, most of the communities can hardly access it (no internet coverage, no IT knowledge, limited equipment, etc.)

3 Results

3.1 Charcoal production patterns

This chapter presents the analysis of the charcoal production patterns survey among the 48 charcoal producers in Phnom Aural and Koas Krolar.

As illustrated in figure 4, the date of charcoal production start clearly shows two different patterns between Phnom Aural, where the amount of producers is rising in a linear way, and Koas Krolar, where three phases can be distinguished: 2004-2006; 2006-2011 and 2011-2014. These different dynamics were studied more in detail in the community workshop section.

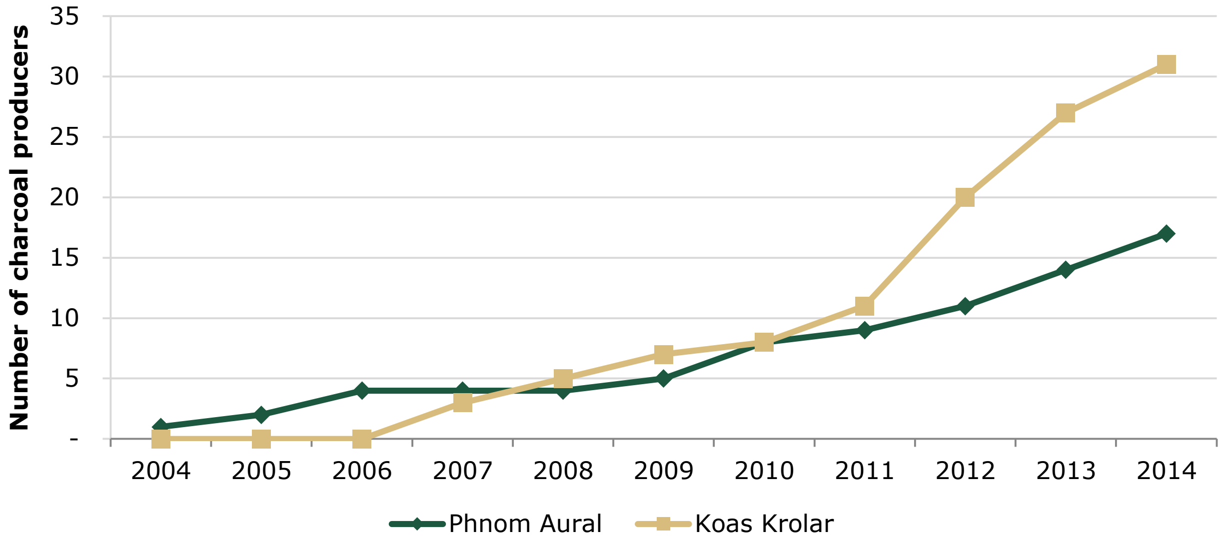

Figure 4 – Date of charcoal production start per producer (accumulative, n=48)

The two areas also differ in the economic profile of the charcoal producers. Phnom Aural shows a higher share of full-time producers for whom charcoal production represents the main source of income whereas charcoal is a secondary source of income for the majority of the producers surveyed in Koas Krolar.

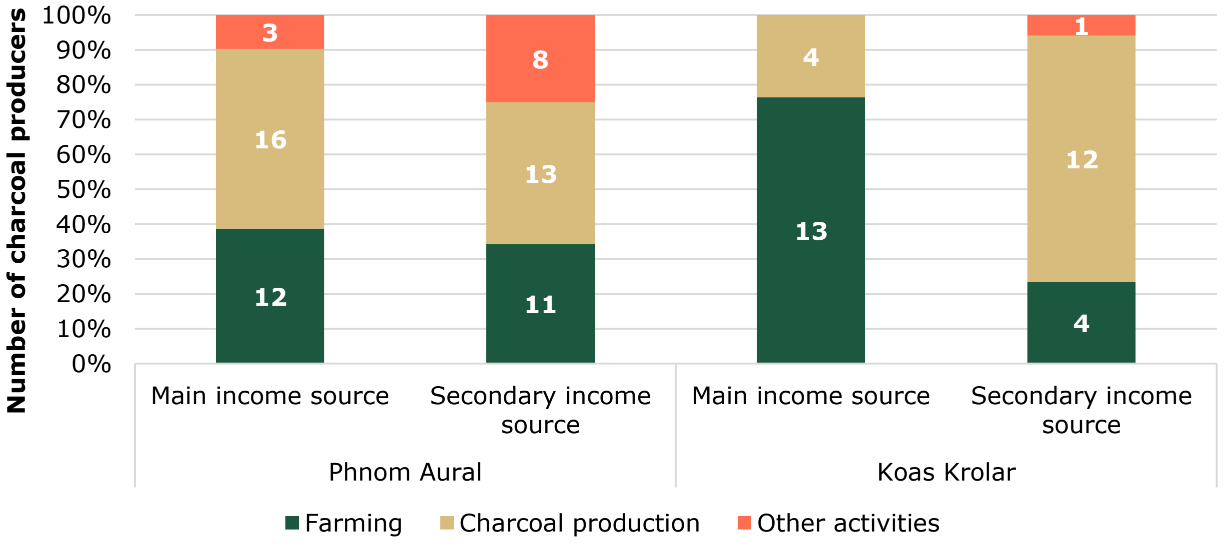

Figure 5 – Share of charcoal among charcoal producers' income (n=47)

Charcoal is a rather lucrative activity compared to the other opportunities in the studied areas, with an average monthly income of 168 USD as shown in the boxplot below. This figure, however, doesn't represent the monthly net profit, as some costs such as bribes or gasoline for wood collection are not deducted. These costs seem to be highly variable.

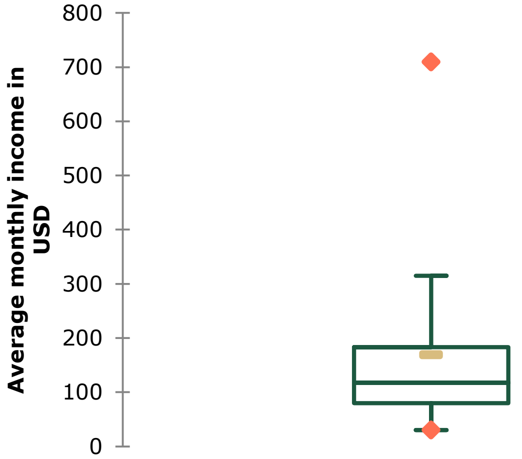

Figure 6 – Distribution of the average monthly incomes in USD (n=31)

Incomes from charcoal production are not consistent throughout the year. In fact, charcoal production often provides an additional income to rice production and is traditionally a dry season activity for two main reasons: (1) charcoal producers are busy with paddy field work during the rainy season and mostly looking for complementary income during the dry season and (2) conditions are not adapted to wood collection during the rainy season. Therefore, the production patterns decrease at the start of the rainy season and at the beginning of paddy production. However, among the 48 charcoal producers surveyed, 17 producers reported that they store wood collected during the dry season to extend the charcoal production period during the rainy season, especially in Phnom Aural where many producers do not own any crop land and are fully specialised in charcoal production.

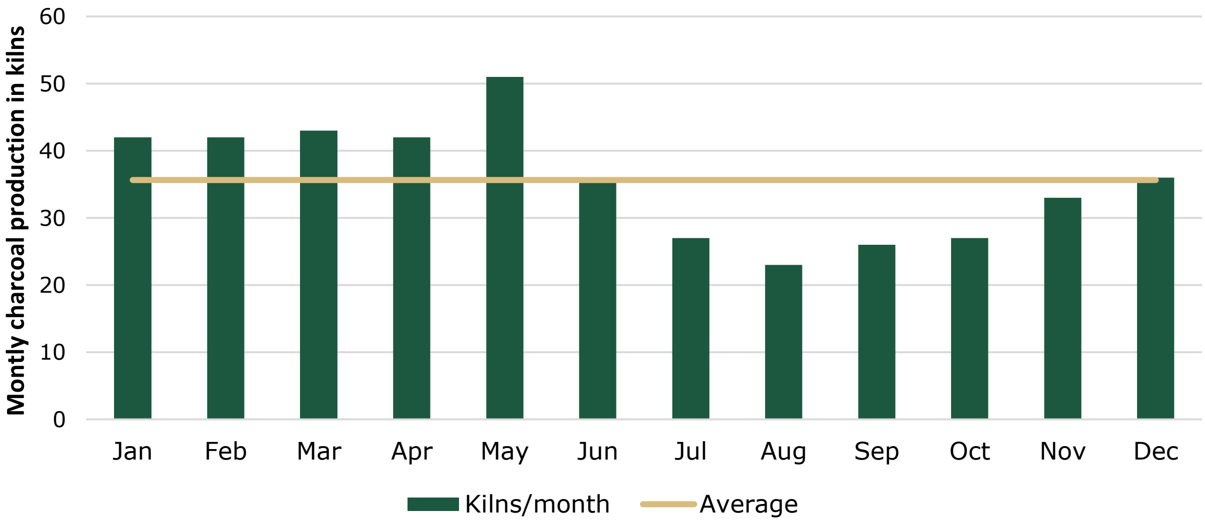

Figure 7 – Charcoal production per month in number of batch produced among the 48 producers surveyed (1 batch=1 cycle of pyrolysis in the kiln).

As for the origin of the wood, the patterns between Phnom Aural and Koas Krolar are significantly different. In Koas Krolar, 100% of the wood harvested by the producers surveyed was coming from forest conversion to agriculture, while in Phnom Aural the origin was more diversified. In the case of Koas Krolar, charcoal production seems to depend on a more structural driver of land-cover change which is agriculture. In Phnom Aural, the dynamics appear more complex with interactions between important land-cover change due to Economic Land Concessions and illegal harvesting in community forest land and natural forest, which in this case points to charcoal as a driver of forest degradation. These differences are shown below in Figure 8.

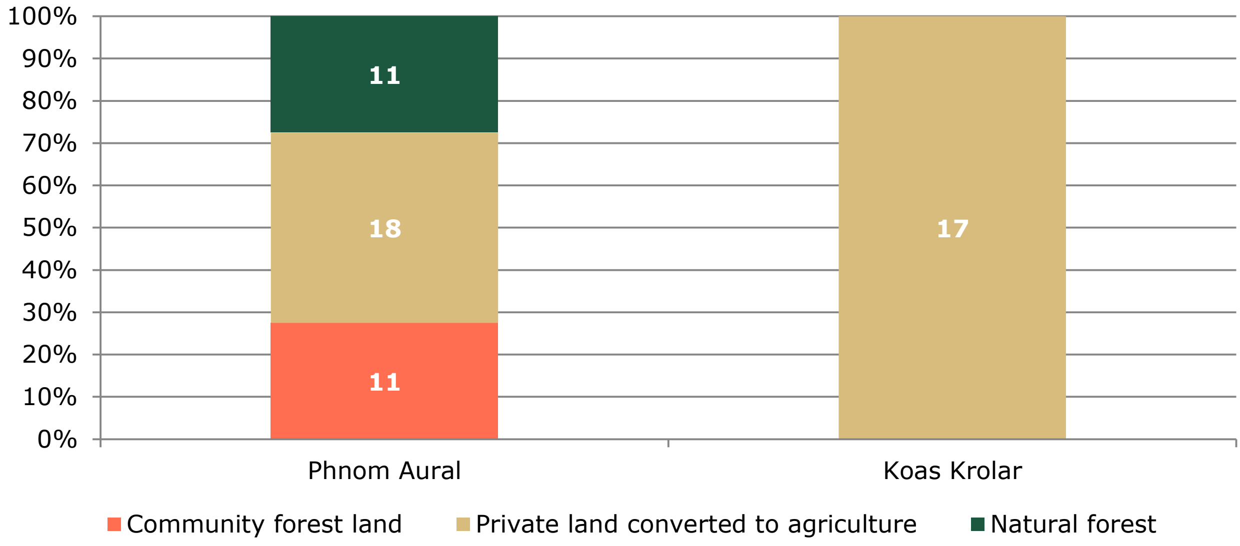

Figure 8 – Wood origin for charcoal production per study area (n=48)

The wood procurement techniques are quite similar between the two studied areas and show (in figure 9) that the majority of the trees were directly cut by charcoal producers, thereby contributing to the degradation of forests. The share of producers collecting wood from former forests that were recently clear-cut by other drivers of deforestation, such as farming, is significant. All the producers surveyed collected the wood for free; which would make it difficult for charcoal produced from sustainable forest resources to compete with the informal charcoal market.

Figure 9 – Wood procurement for charcoal production per study area (n=48)

The main species collected for charcoal are *Shorea Obtusa*, *Irvinga Malayana* and *Xylia Xylocarpa.* These 3 species have timber market potential, especially since our field observations revealed that trees cut for charcoal often have a diameter wide enough for timber purposes. Thus, it shows that the management of wood resources regarding their final purpose is not optimal. However, two thirds of the producers surveyed indicate that intermediary charcoal buyers have quality requirements, especially on the size of charcoal pieces (customers seem to prefer big section) and on the wood species. This last observation highlights the need for programs to address the whole charcoal supply-chain from forests to end-users.

3.2 RELATIVE IMPACT OF CHARCOAL ON FOREST LOSSES

3.2.1 CHARCOAL PRODUCTION AND RESULTING VOLUMES OF WOOD DEMAND

The 24 hour checkpoints show that the largest amounts of charcoal are transported during the early morning; confirming a previous study done by the Ministry Of Mines and Energy in 2009 with the technical support of GERES[33].

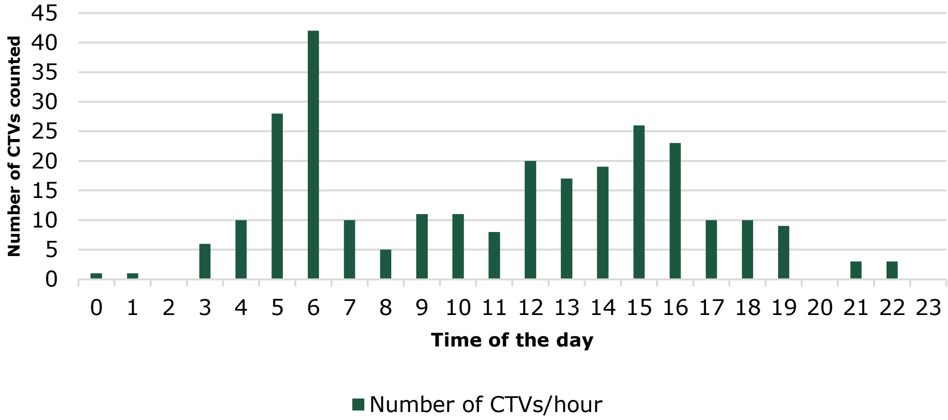

Figure 10 – Number of charcoal transportation vehicles (CTV) per hour

The most important amounts of charcoal flows were recorded in Kampong Speu province between Phnom Aural and the national road n°4 in the direction of Kampong Speu city and Phnom Penh with more than 50,000 tonnes of charcoal per year, representing approximately more than 320,000 tonnes of initial wood annually.

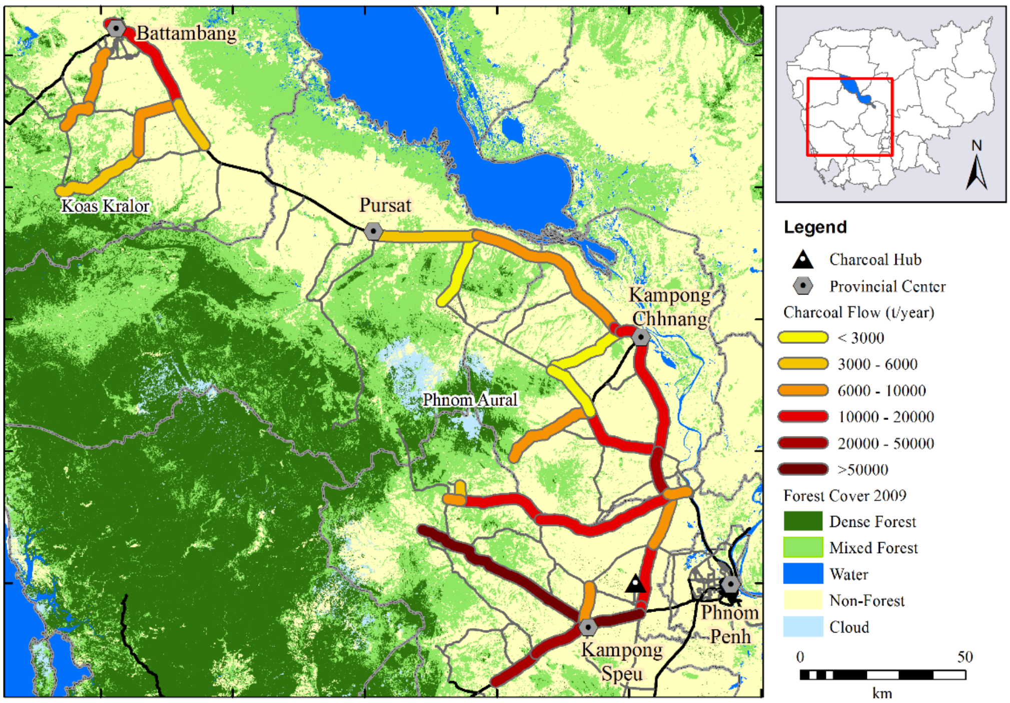

Figure 11 – Charcoal flows in the Northern Cardamoms estimated from the 24 hours checkpoints

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[33] Kong Pagnarith, 2007. Wood & Charcoal Supply Study for Rural Energy Balance In Kampong Speu Province. Ministry of Industry Mines and Energy (MIME).

To account for the impact of charcoal production on the forests of the two study areas, the results of the 24h checkpoints were processed to avoid double counting. Only 13 tracks (combination of one origin and one destination) were selected out of 25 recorded to ensure conservativeness of the results. Then, these values were adjusted through weighting factors based on the number of charcoal kilns fired per month among the 48 producers surveyed (see graph #6).

The charcoal producer survey indicated that the month of December corresponds to the annual average production of the producer surveyed (cf. fig 7). However, due to project timeframe constraints, 24h charcoal vehicle counting along the supply roads could not be done after November. Therefore, the amount of CTVs counted in November has been adjusted by using weighting factors based on the month by month seasonality. Weighting factors allowed the team to estimate the annual production from 24h counting conducted in November.

Table 1 - Weighting factors to extrapolate November CTV counting to annual CTV flows

Province	Weighting factor
Kampong Chhnang	12.24
Kampong Speu	11.04
Battambang	15.36
Total	**12.96**

Total charcoal production for the 2 studied zones was estimated at 148,718 metric tonnes per year (cf. figure 12). Considering that only 80%[34] of the Above Ground Biomass is suitable for charcoal production (traditional production does not allow charcoal production with small diameter branches) and that 6.41 kg of wood is needed to produce 1 kg of charcoal[35], the charcoal produced in the two study areas would represent a demand of 1,191,604 tonnes of wood per year.

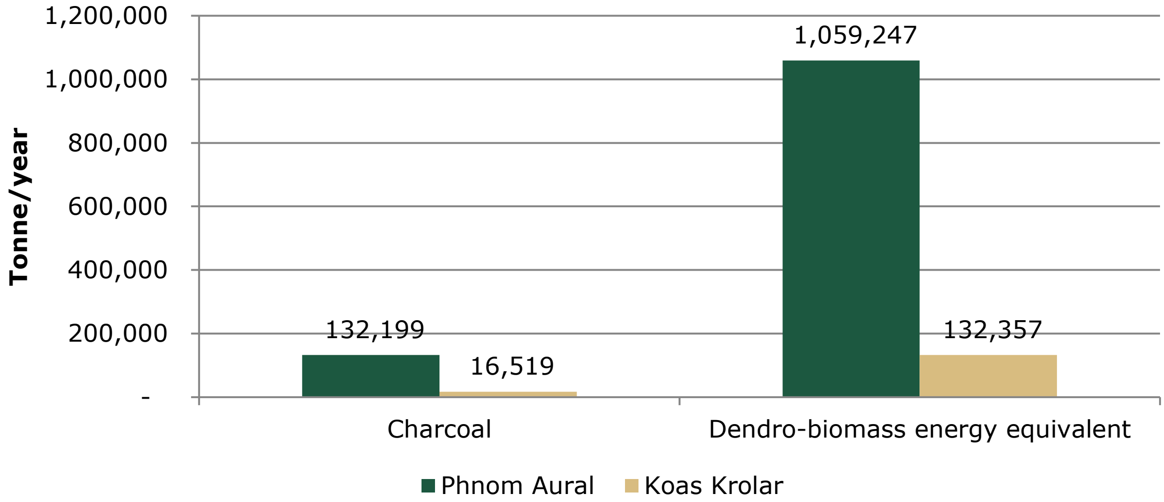

Figure 12 - Annual adjusted quantities of wood-equivalent extracted from study boundaries

In comparison, a study currently undertaken by GERES[36] estimates that the annual consumption of charcoal in Cambodia reached 336,000 metric tonnes in 2013, meaning that the two study areas would provide for 44% of the estimated national consumption. This figure confirms the relevancy of the CTV counting conducted in November 2014 as it is known that the Aural Mountain is the main area of production for supplying the capital Phnom Penh. According to discussions with local experts and interviews with charcoal traders in many provinces, Kampong Thom and Bantey Manchey provinces, located on the other side of the great Tonle Sap Lake, and Preah Sihanouk and Koh Kong, located at the South of the Cardamom Mountains), would provide the other half of charcoal demand in Cambodia.

[34] Robert Bailis et al., « The carbon footprint of traditional woodfuels », *Nature Clim. Change* advance online publication (19 janvier 2015), http://dx.doi.org/10.1038/nclimate2491.
[35] GERES internal studies.
[36] GERES, 2015. Nation-wide assessment of biomass consumption patterns from domestic and industrial activities in Cambodia. To be released soon.

Results from another CTV counting conducted by GERES[37] in 2005 at the same period of the year (November 22nd and November 24th) reported a flow of 89,694 metric tonnes of charcoal transiting from Kampong Speu to Phnom Penh for 2005, suggesting that charcoal produced in the Aural mountain increased by 47% within nine years.

3.2.2 BIOMASS STOCKS AND CHARCOAL PRODUCTION AREAS

The assessment of the forest supply area for charcoal production is highly uncertain. Indeed, the charcoal producers have been located through a snowball approach, which supposes a higher probability to account for producers near the roads than producers more in depth in the forest. Moreover the reported variation of the supply area around each kiln is very high indicating a non-homogeneous pressure between the forest areas close to the villages and the ones more difficult to access. To discuss these uncertainties and the related potential impacts of wood extracted for charcoal production, three potential supply areas have been defined. These supply areas have been defined using a supply buffer around each charcoal kiln located. Three different buffers have been studied, with values of 10 km, 20 km and 30 km. All these values are below the highest travel distance from charcoal kiln to forest.

The estimation of biomass stocks in each potential supply area have been studied through the use of a linear regression (figure 13) between forest cover and above ground biomass from in-situ forest inventories. The forest cover was at the time of this study the only proxy available on GFW platform with a reasonable resolution to estimate the biomass stock. However, the prediction capacity of the above ground biomass using the forest cover remains very limited (R^2=0.48). Therefore the regression developed has an important uncertainty with a confidence interval of 90% as shown in the figure below. The assessment of the biomass loss rate is one of the main limitations of the assessment of charcoal's contribution to biomass loss.

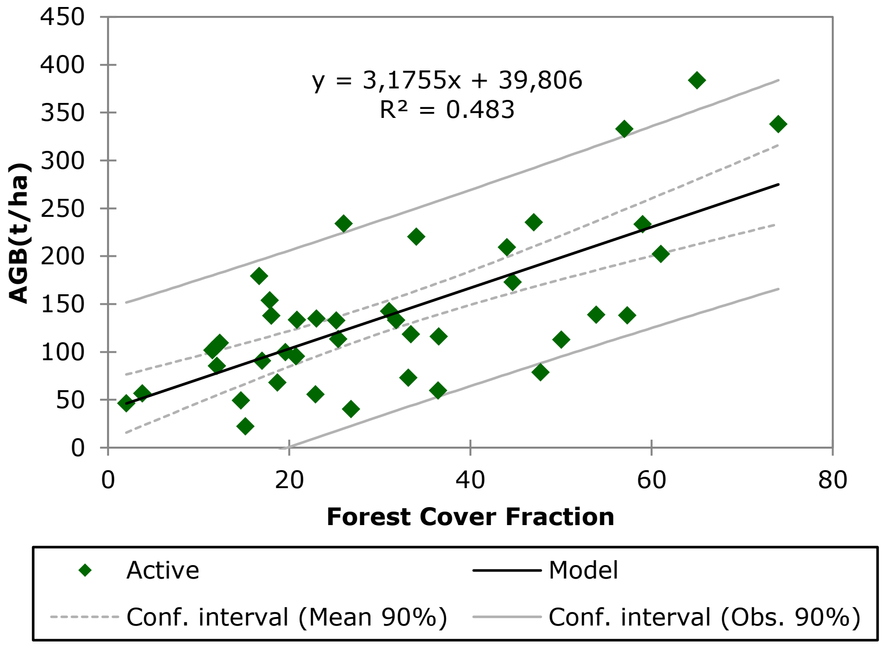

Figure 13 – Regression between the Above Ground Biomass and the Forest Cover Fraction

Based on the results of the regression the quantity of biomass loss per year has been estimated and is presented the following figure.

[37] E.R. Van Mansvelt, M.C. Le Quan, S. Im, E. Buysman, R.K. Anaya De La Rosa, A. Guidal, 2009. Wood Energy Baseline Study for Clean Development Mechanism in Cambodia Household woodfuel use and supply in Phnom Penh.

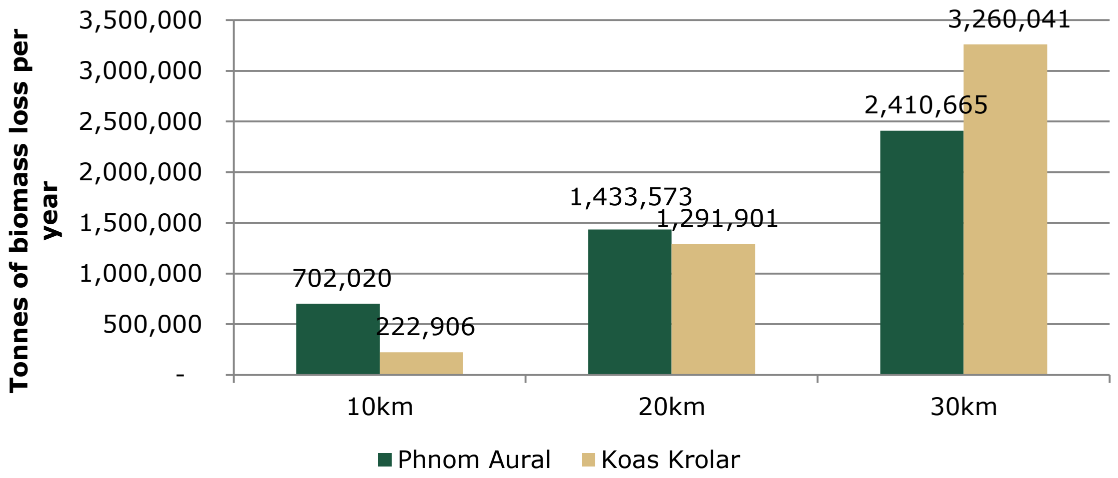

Figure 14 – Estimations of biomass loss in the study areas according to the supply radius around charcoal kilns considered

To estimate the sustainability of charcoal, the annual growth rate of the biomass per hectare has been calculated using the above ground biomass previously estimated and the following equation developed by Top *et al.* in Kampong Thom province in Cambodia.

$$\mathbf{GR = 2.36 \times ln(AGB) - 7.79}\ (R^2=0.42)$$

Equation 1 – Annual growth rate per above ground biomass[38]

The growth rates obtained are more conservative than the ones from the UNFCCC methodology which is currently used as a reference to estimate the impacts of charcoal on climate for carbon finance projects. Growth rate values range from 1.27 tonnes/year to 1.47 tonnes/year depending on the case study and supply areas considered whereas the value used by UNFCCC is 4.09 tonnes/year[39].

For the total area of growing forest, the total annual biomass growth (Mean Annual Increment of the Biomass) has been calculated. The value increases as the supply areas considered gets bigger. The highest is the Mean Annual Increment the highest is the estimation of the sustainability of charcoal.

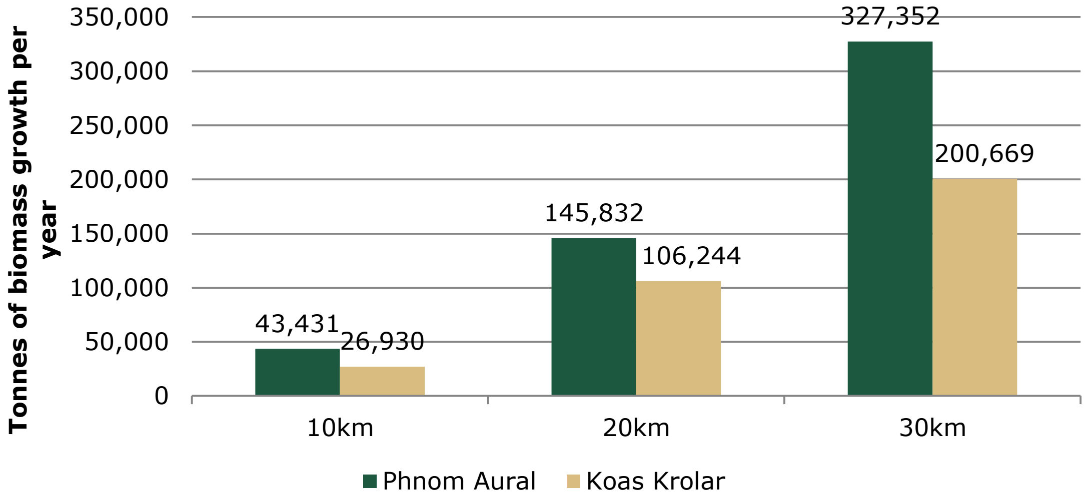

Figure 15 – Estimated Mean Annual Increment in the study areas according to the supply radius around charcoal kilns considered

[38] Top et al., « Re-assessment of woodfuel supply and demand relationships in Kampong Thom Province, Cambodia ».
[39] UNFCCC SSW-WG 35th meeting – annex 20 – "Default values of fNRB for LDCs and SIDs"

3.2.3 Assessment of the sustainability of charcoal production

As presented in the previous chapters, land-cover change dynamics and charcoal production patterns vary significantly between the two areas studied. The following map (figure 16) illustrates the importance of agriculture as a major driver of deforestation.

In Phnom Aural, most of the deforestation happens in Economic Land Concessions (ELCs), which account for a significant part of the potential wood supply areas. Nevertheless, another part happens directly in the Phnom Aural Wildlife Sanctuary although the share of accessible forest in the sanctuary is probably limited (mountainous forest with very steep slopes make log transportation difficult). Surveys and the community workshop also reveal that significant forest degradation is taking place, which can hardly be spotted through remote sensing and which is not visible on the map (figure 16).

For Koas Krolar, there are no ELCs and no public data available on the land-cover change drivers. However, the field surveys and the community workshop stress that most of the current deforestation is due to forest conversion from small or medium size agricultural land (no ELCs in the area but medium size farmers or investors).

The results from the surveys confirm these observations as 45% of the producers interviewed in the Phnom Aural sample are sourcing wood from Economic Land Concessions, while 100% of those interviewed in the Koas Krolar sample collect wood from forest areas being converted to agricultural land by existing farmers.

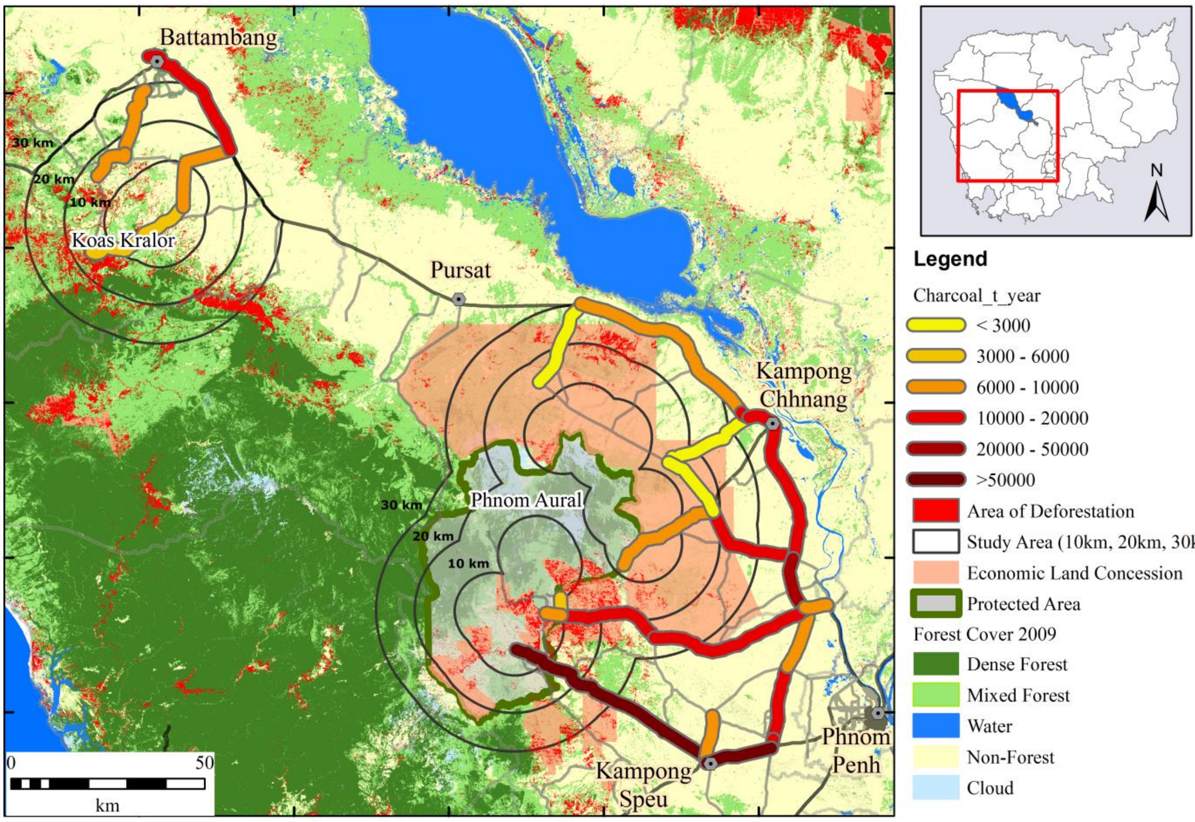

Figure 16 - Mapping of forest losses and potential supply areas

The following diagram (figure 17) presents the relative contribution of charcoal to biomass losses in the study areas according to two scenarios. The first one considers whole wood harvested for charcoal compared to the deforestation in the study area. The second one excludes the estimated share of wood coming from conversion to agriculture.

These results encompassing every wood origin stress that the supply-area of 10 km tends to overestimate the impact of charcoal, especially for Phnom Aural, and support the use of a more realistic 20 km or 30 km radius of supply around the charcoal kilns. In this case, charcoal would represent 74% and 44% of total biomass losses for Phnom Aural and 10% to 4% for Koas Krolar. Considering only charcoal as a main driver of forest degradation (excluding the wood sourced from agricultural conversion) the share of charcoal in the biomass loss drops between 41% and 24% for Phnom Aural and is considered null for Koas Krolar.

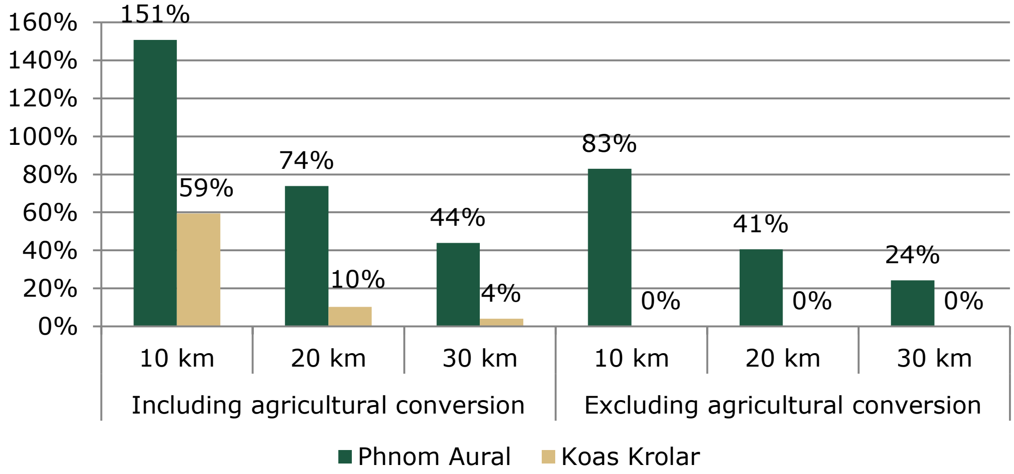

Figure 17 - Contribution of charcoal to biomass losses according to the potential supply radius

The following graph (figure 18) presents an estimation of the fraction of non-renewability of charcoal. This fraction considers the share of wood harvested for charcoal that is "non-renewable" or more precisely non-sustainable. In the first case, the estimated share of wood coming from agricultural conversion is considered as non-renewable at 100% and the wood sourced in other areas is considered non-renewable if the volumes harvested are higher than the Mean Annual Increment. The second case considers only the wood sourced from public or community forests, and represents the impact of charcoal as a main driver.

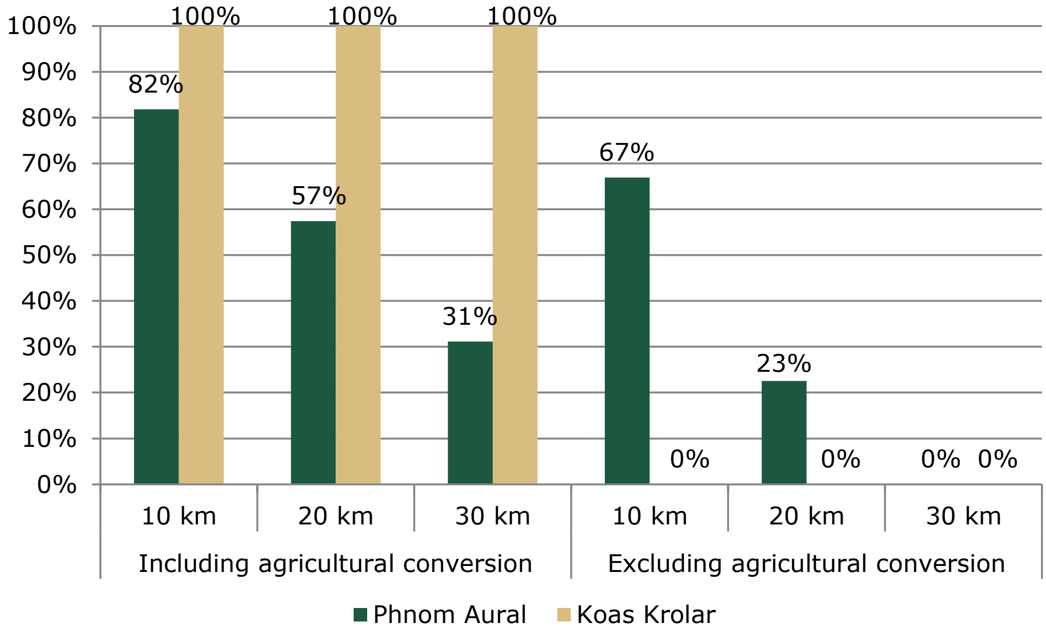

Figure 18 – Fraction of non-renewable biomass (fNRB) according to the supply radius and the inclusion of charcoal originating from agricultural conversion

These results show the important variation of the potential fNRB according to the methodological approach chosen and the potential supply area considered. These methodological differences are more significant in Koas Krolar where 100% of the wood collected for charcoal is sourced from land converted to agricultural land. The fNRB varies from 100%, if we consider that the land-use change will not allow regrowth, to 0%, if we consider that a decrease in charcoal production will have no impact because charcoal production benefits from anther deforestation driver which is agriculture to produce agro-industrial crops (soya bean, cassava, green bean).

3.3 STAKEHOLDERS' PERCEPTIONS AND FEEDBACK

Case study n°1: Phnom Aural – Feedbacks from the community workshop

Phnom Aural has been the traditional source of charcoal for the Cambodian capital. It also represents one of the last forest wilderness areas in mainland Southeast Asia. It contains two community forests of 3,083 ha and 2,446 ha respectively, as well as 253,750 ha of Wildlife Sanctuary nearby. Before 2005, small amounts of wood were extracted from the forest except for local fuelwood consumption and construction timber. Few tree species were selected, cut manually and transported by ox-carts to the villages, taking one to three days. At that time, forest degradation was highly confined spatially and affected mostly specific luxurious timber species. Besides, non-timber forest products were an important source for local livelihood.

Conflicts started between local villagers, newcomers who secretly logged into the forest, and private companies[40] who have cleared thousands of hectares of forest to grow agro-industrial crops. Local villagers started charcoal production due to poverty caused by long droughts, decreasing agricultural yields and lack of alternatives within this area, but also due to the significant incomes reported by charcoal producers nearby. At that time, plenty of cleared wood remaining from agricultural conversion was available; so the incentive of charcoal production became increasingly important. According to the villagers, forest has been haphazardly cut and cleared by both villagers (inside and outside) and private companies. Main drivers of deforestation were agricultural activities and timber; remaining trees were used for charcoal. Nowadays, the forest which was normally full of large trees (hugged by 2 or 3 people) became forest which consists of small trees (handed with one single hand). Even the community forest is degraded. According to the perception of local villagers, forest cover has changed from 90% in 2001 to only 5% nowadays.

They feel that these important changes in the landscape affect their agricultural yields. Trees are a major sources of shade, ensure rain and are natural fertilizers. With the ongoing degradation, temperatures seem to increase. As a result of decreasing and irregular rainfall patterns, the water supply for farming has become a major issue for these self-sufficient communities traditionally relying on rice. Good yields can be observed only in farms having access to irrigation. soil quality is also decreasing and the use of chemical fertilizers seem to be increasing from year to year. Soil fertility reduction (less organic matter) was also reported.

The depletion ecosystem services provided by forest impact agriculture and thus increases the need for an alternative income generating activity such as charcoal, amplifying the degradation process.

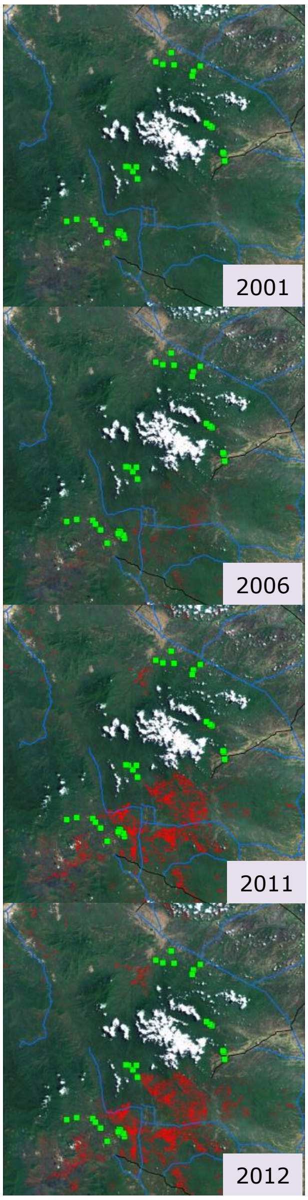

Figure 19 – Location of charcoal producers (green spots) and deforestation (red spot) in the area of the community workshop

[40] For more information : http://www.phnompenhpost.com/national/memories-land-unspoiled

Case study n°2: Koas Krolar - Feedbacks from the workshop leader

After explaining the map of forest loss in their area, people who witnessed this long event were not surprised at all. Instead, they spontanously responded to why it had happened and pointed out the locations where it occured. The loss of forest cover started in 2001. It happened when the Cambodian Mine Action Centre (CMAC) started to clear unexploded ordnances within the area. At the same time, local villagers claimed land rights on forest plots provided by the Royal Government of Cambodia. Producers reported that the larger forest lands belonged to "powerful people" where smaller plots belong to local villagers.

Between 2001 and 2006, small fragments of forest were manually cut and converted to paddy fields while larger areas of forest remained untouched. The discussion with local villagers underlined that those large plots have been sold several times and are now fragmented into a large number of owners. The trees cut for land conversion into paddy field by villagers have been valued into firewood, charcoal, and timber for construction. In addition, some selected wood was collected from unexploited large private forest lands. Charcoal production was still limited at that time.

After 2006, the area of forest converted to agriculture was increasing dramatically. Large blocks of forest land were cleared for agricultural crops such as maize, sugar cane and cassava. During this period, people from other villages also moved to this area and bought forest land for agricultural production. From the local villagers' perspectives, at the beginning of 2011, only 20% of the initial forest cover remained. Charcoal started to increase slightly but it remained negligible compared to agricultural activities. Some logs were given to charcoal producers by some large land owners while plenty of trees were burned on site secretly.

Charcoal production has dramatically increased in recent years (2013-2014) in parallel with agricultural surface expansion. Today, local villagers state that less than 5% of the forest cover remains and they expect that in 5 or 10 years, forest in this area will be completely depleted if no reforestation activities are undertaken. Charcoal production seems to decrease with a supply higher than the demand and producers feel that they might have to stop soon considering the high rate of forest depletion.

Farmers attending the event also reported erratic weather patterns since 2006. Irregular rainfall and longer periods of drought seem more frequent now. "There is water scarcity when it is needed and more intense floods when it's not expected", said the villagers. A few farmers can still get good yield from their land as they stay close to irrigation facilities. Villagers also reported soil quality degradation from year to year as the use of chemical fertilizers is increasing. The villagers expect their yield to continue to decrease in the next 5 or 10 years if no change in farming practices occur. After an increase in population in the study area between 2001 and 2006, there is now a decrease due to emigration. "This rising rate of migration is highly linked with reductions in agricultural yield and a lack of water supply", they said.

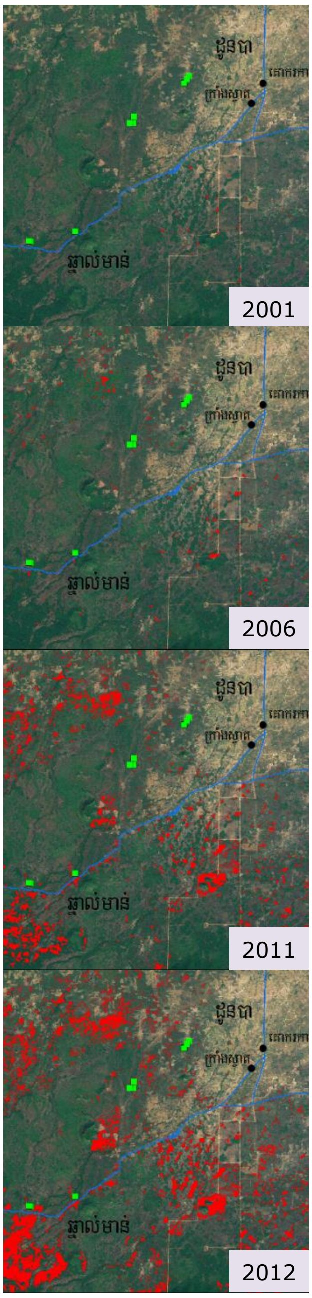

Figure 20 - Location of charcoal producers (green spots) and deforestation (red spots) in the area of the community workshop

4 Discussion and Conclusion

This study shows that the impact of charcoal production on forests is highly connected with landscape changes and cannot be isolated from agriculture or other drivers of forest degradation or deforestation. Charcoal producers, who cannot be classified in a single homogeneous group, are part of a complex system encompassing high-power international and national actors which also drive the changes in the landscape. The impact of charcoal production on forest degradation varies a lot geographically, as shown with the different patterns between Phnom Aural and Koas Krolar. It also varies across time as charcoal production could be opportunistic for a given period of time, fuelled by forest conversion into agricultural land and then sourced from remaining forests, becoming a direct driver of forest degradation. Thus, it is challenging to isolate the impact of charcoal on forest resources among other drivers. In fact, in addition to the land cover changes for agriculture, the assessment of the charcoal impact on forest resources should consider the wood harvested for timber and firewood, which was not possible in this study.

The quantitative assessment provided in this study is limited by the uncertainty of some key factors. Firstly, biomass losses are estimated as a function of the forest cover which is a limited predictor of the Above Ground Biomass, as presented in the previous chapter. Then, the Mean Annual Increment does not account for competitive uses of biomass, especially timber and firewood, leading to an overestimation of the sustainability of charcoal. Most of all, this study highlighted the high sensitivity of the results to the supply area considered. This is especially the case for Phnom Aural, where few available forests remain due to massive land conversion to Economic Land Concession around the Wildlife Sanctuary. Field geolocation of the wood collection areas shows that a significant part of the charcoal is sourced inside the Wildlife Sanctuary which should therefore be included in the calculation of the fNRB.

It also appears that time is a key element in the assessment of the impacts of charcoal production. Unless land is completely cleared for future crop land, supply areas are not fixed. Former harvested areas could partly regenerate in the future while other areas could be degraded. In both study areas, large amounts of forests are currently under massive conversion to Economic Land Concessions or smaller-scale private farming. Although charcoal can be perceived as a minor issue in these areas, it may not be the case in the future if conversions to agricultural land stop. However, inclusion of time would also require accounting for the elasticity of the charcoal demand to price as a factor of scarcity, making the assessment even more complex and uncertain.

Assessing the impacts of charcoal on the forests requires assessing the local dynamics of land-use change, and especially agriculture. By not considering specifically the wood extracted for charcoal production or the local dynamics of land-use change, the current carbon finance methodologies for woodfuel projects using fraction of non-renewable biomass (fNRB) are likely to overestimate the impact of a reduction of charcoal consumption and therefore its impact on greenhouse gases emissions. The findings of this study are in line with the recent findings of R. Bailis *et al.* (2015), published a few weeks before the release of this study in Nature Climate Change[41].

The approach developed allowed for the identification of the main charcoal production areas as potential "hotspots" for project intervention and highlighted contrasting charcoal production patterns. These different patterns stress the need for adapted "Theory of Change" to tackle issues related to charcoal production. In Phnom Aural, charcoal appears to be a key driver of forest degradation. Better governance of this informal sector and reduction of wood demand is necessary to stop this long-term depletion. On the other hand in Koas Krolar, such activities would have a very limited impact as charcoal is more a by-product of another driver of deforestation. The same project in these two areas would then have two completely different impacts on forests according to the local dynamics.

The current depletion of forests and its effects on ecosystem services combined with the expected high impacts of climate change in the region will strongly affect the livelihoods of charcoal producers by impacting their main sources of income (NFTPs, rice farming). It could increase the importance of charcoal to generate income and therefore speed up the current depletion of forests, leading to the end of charcoal production itself in the studied areas; probably shifting to other forested areas as the urban demand remains. Through the project, communities already reported degradation of soil capital, erratic rainfall patterns and first emigration waves, showing that the change is already happening.

The study stressed the significance of charcoal production in Cambodia for local communities of producers but also for supply to urban households. Despite this critical importance, the legal framework governing forest use by local communities is highly restrictive, making the whole charcoal sector

[41] Robert Bailis et al., « The carbon footprint of traditional woodfuels », *Nature Clim. Change* advance online publication (19 January 2015), http://dx.doi.org/10.1038/nclimate2491.

technically illegal while they currently address a huge and obvious demand from the urban areas of Cambodia.

Tackling the issues related to charcoal in Cambodia requires a more holistic approach which integrates all the drivers of deforestation and forest degradation through mechanisms like REDD+ and which addresses the vulnerabilities of local populations relying on charcoal production. The participatory approach developed and implemented during this project proves to be a relevant and cost-efficient approach to identify "hotspots of degradation", assess the local dynamics of landscape evolution and support the design of adapted projects in selected areas where actions related to charcoal production can significantly contribute to decreased pressure on forests.

Another conclusion of this study is that community workshops are a highly cost-effective approach to tackle the complexity of this type of assessment and understand the dynamics of land cover change in a given area. After an introduction by trained local community facilitators to locate the village and different roads leading to the forests, the villagers are fully capable of describing the dynamics that have been ruling their landscape for more than a decade of land use change. For example in Koas Krolar, no data about private concessions were available. However, villagers provided enough feedback to fully understand local dynamics and the power relations that drive them. At the end of the project, the understanding of Koas Krolar area was as good as in Phnom Aural for which the team had much more information from the beginning. Stakeholders' interactions and the multiplicity of actors and issues are such that a GIS and quantitative statistical analysis will never be able to provide a full understanding of the socio-economic issues driving the depletion of forest resources, especially in developing countries like Cambodia.

The GFW platform revealed itself and turned out to be a very powerful and cost-effective tool to analyze past deforestation and forest degradation in a given area and engaging the communities relying on these forests in a discussion on the different futures of the landscape and which actions could tackle current trends. Such participatory uses of GFW implemented at a wider scale could draw a comprehensive analysis of the issues affecting forest ecosystems and pave the way towards a more systemic approach of forest resources management in tropical countries.

Annex : Typology of Charcoal Transportation Vehicules (CTV)

Type of Transportation	Description	Weight in kg	Picture
Koyon Kantray A	Approx. 2.5 m length, 1.6 m width, and 1 m height.	800	
Koyon Kantray B	Approx. 2.5 m length, 2 m width, and 1 m height with cover.	1000	
Koyon Kantray C	Approx. 2.5 m length, 2 m width, and 2 m height.	1500	
Koyon Kechhnay D	Approx. 4 m length, 1.5 m width, and 2 m height.	4000	

Type of Transportation	Description	Weight in kg	Picture
Giant Reumork E	Approx. 4 m length, 1.5 m width, and 0.7 m height.	4000	
Medium Reumork F	Approx. 2.5 m length, 1.9 m width, and 0.6 m height.	3000	
Small Remork G	Approx. 2 m length, 1 m width, and 0.5 m height.	700	

Type of Transportation	Description	Weight in kg	Picture
Mini-bus (Sanyong) H	Korean mini-bus can carry 62 bags (unit bag of 40 kg). They are put in and on the bus.	2500	

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