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Extractive industries, livelihoods and natural resource competition: Mapping overlapping claims in Peru and Ghana

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A B S T R A C T

Taking the cases of Perú and Ghana, this paper examines overlaps between the extraction of minerals, oil and gas on the one hand, and river basins, agricultural land use, and protected areas on the other hand. In particular the paper considers how far such overlaps can be revealed and analyzed on the basis of (relatively) accessible and affordable data, without having to use more expensive data generated by remote sensing or fieldwork. We use concessions as our indicator of the presence of extractive industry activity, focusing on both mineral and hydrocarbon concessions, and areas of exploration and of active resource exploitation. High portions of agricultural land use in both countries are located within areas that are subject to mineral or hydrocarbon concessions (38% in Perú, 39% in Ghana), predominantly within areas in which exploration activities are permitted or occurring (36% in Perú, 35% in Ghana). While overlaps between concessions and areas protected for conservation were much smaller (10% for Perú, 2% for Ghana), concessions overlapped with a larger portion of titled indigenous communities in Perú (35%). These findings help visualize the geographies of uncertainty and risk that the expansion of extractive industry creates for populations dependent on agriculture, land, water and other resources in areas affected by concessions. The visualizations – and the evidence of quite different degrees of overlap, depending on the type of resource in question – suggest the relative strength of different modes of land and resource governance in the face of extractive industry. Notwithstanding their well-documented fragilities, institutions for habitat conservation seem to have been better able to resist pressures on them from the extractive sector than do those for regulating water resources, agricultural land and indigenous communities which appear far less able to moderate the expansion of resource extraction.

Introduction

Investment in mining, oil and gas, the "extractive industries," has increased globally in recent decades, spurred by especially rapid growth in specific countries (Bebbington and Bury, 2013, 361 pp.; Bridge, 2004). This investment takes geographical form, expanding into spaces that are anything but "empty" (Deininger et al., 2011; Müller & Munroe, 2014). While these spaces might be new frontiers for extractive industry, in most instances they and the natural resources that exist within them are already occupied, used, claimed and governed by other social groups. These prior claims and uses might be related to production (as when these resources are already used for agriculture), material consumption (as when these spaces are sources of water for communities and towns) or cultural significance (when these spaces are symbolically important or areas of recreation) (Bebbington & Williams, 2008; Bury 2005; Finer, Jenkins, Pimm, Keane, & Ross, 2008; Lynch, 2012). Some of these uses, claims and occupations might be grounded in law (when there are juridical rights) while others are grounded in custom (when there is a long, historically constituted practice) (Budds & Hinojosa-Valencia, 2012). Some might exist in the present (e.g., areas currently used for agriculture), while others might exist in the future (e.g., areas understood by one or other actor as having agricultural potential). While some prior claims and uses are those of powerful actors (e.g., national systems of protected areas), more often than not, these spaces are occupied and used by actors who are far less powerful than the extractive industries now claiming access to the same resources and spaces (Bebbington, 2012; Bury, 2005).

While this competition for space and resources *could* lead to co-existence and synergies among forms of land use, in many instances it has led to conflict (Arellano-Yanguas, 2012; Hilson, 2002; Maconachie & Binns, 2007). This paper constitutes one point of

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entry into making sense of such processes by using visualization, cartographic representation and spatial analysis to explore the potential relationships among different types of land use/land cover, and to propose techniques that can provide initial, pre-field proofing insight into the implications for livelihoods in areas within the vicinity of extractive industries (in this sense we build on work by authors such as Bury (Bebbington & Bury, 2009) and organizations such as Cooperacción [www.cooperaccion.org.pe]). The analysis is conducted for the cases of Perú and Ghana, both countries with significant and growing extractive sectors (Bebbington & Bury, 2009; Hilson & Garforth, 2013; ICMM, 2007). The two countries share long colonial histories of mining activity (Addy, 1998; Orihuela & Thorp, 2012), while having also experienced more recent growth in investment in hydrocarbon extraction (Finer, Jenkins, Keane, Pimm, 2008; Finer, Jenkins, Pimm, et al., 2008; Throup, 2011; Van Gyampo, 2010). In each country, increased investment in extractives has occurred in a context in which the state, though not strong, demonstrates some capacity for planning and regulating economic activity (Daviron & Gibbon, 2002). Finally both Ghana and Perú have large agricultural economies, with some parts of the country characterized by important export oriented sectors but yet more extensive areas characterized by rural livelihoods dependent on water-constrained agriculture and particularly severe poverty incidence (Budds & Hinojosa-Valencia, 2012; Crabtree, 2002; Finan, 2007; Hilson & Garforth, 2013; Läderach, MartinezValle, Schroth, & Castro, 2013; Ntiamoah & Afrane, 2008). The two countries thus share the challenge of having to manage relationships between two sectors (resource extraction and agriculture) that are each important for economic growth and poverty reduction. The comparison therefore helps us say something about the relationships between extractive industry, agriculture and natural resources in countries with a certain “mining identity,” a policy commitment to enhanced resource extraction in both the mining and hydrocarbon sectors, and a government bureaucracy with some potential capacity to regulate (Bebbington & Bury, 2009). Finally, the comparison allows us to explore what can and cannot be mapped on the basis of relatively accessible, affordable and (supposedly) public data in these types of country context. This is important given that most bodies involved in monitoring extractive industries are limited to such data and unable to afford the cost of broad-scale classification of remotely sensed data or of extensive fieldwork. This concern for “feasibility”, we hope, makes the methodological findings relatively more “applicable.”

Extractive industry contexts in Perú and Ghana

Both Perú and Ghana have hard rock mining and hydrocarbon sectors, and in each country the history of hard rock mining is far longer than that of hydrocarbons. Oil was discovered in Ghana only in 2007 (Throup, 2011), while it has a longer twentieth century history in Perú. Each country was characterized by stagnation in its mining sector into the early 1990s. For the case of Ghana, ICMM (2007: 10) notes that “During the years of economic collapse, mining suffered along with other industrial sectors. Indeed, from independence in 1957 to the early 1990s not a single new gold mine was opened.” This stagnation, however, was followed by more recent growth (ICMM, 2007). A similar expansion since the 1990s has been especially rapid in Perú (Bury, 2005). That said, growth has been most accelerated in the hydrocarbons sector, and rapid change in permitted exploration activities has been observed over vast spatial extents. Between 2004 and 2008 hydrocarbon concessions in the Peruvian Amazon increased from covering c. 13–14% of this region to 74% (see Finer, Jenkins, Keane, 2008; Finer, Jenkins, Pimm, 2008; Finer & Orta-Martinez, 2010). Meanwhile, since 2007, the majority of Ghana's near-coastal waters have become subject to hydrocarbon blocks, a feature that also characterizes much of the Peruvian coast. Throup (2011) comments that in Ghana, oil exports are projected to yield $1–1.5 billion p.a., or 6–9% GDP, and that oil is “poised to replace cocoa as the main driver of economic growth.” There is, therefore, much enthusiasm about extractive industries in both countries at the same time as there is discussion of the risks associated with extractives as a path to development. Indeed, each country has experienced pollution, accidents and serious public health incidents related to extraction (Bush, 2009; Slack, 2012).

In addition to a large-scale, corporate extractive sector, each country has a significant artisanal and small-scale mining (ASM) sector. This sector has been particularly well documented for Ghana (Hilson, 2010; Hilson & Garforth, 2012) though has also grown rapidly over the last two decades in Perú (Asner, Llactayo, Tupayachi, & Luna, 2013). ASM activity can be both legal and illicit, and in certain cases (e.g. Madre de Díos in Peru), the areas affected can be extensive. For the purpose of the visualizations produced here we have not distinguished between these legal and illegal forms of mining. While the data on mining concessions will cover some of the ASM and illicit activity, as substantial amounts occur within concessions (Asner et al., 2013), the visualizations will not pick up on extra-legal mining in areas where there are no such concessions. In this sense, the study focuses primarily on corporate, medium and large-scale extraction due to the reliance on authoritative, broad-coverage data. Clearly these different scales and modes of organizing mining imply different sorts of demand on land use and natural resources, different types of relationship between agrarian and mining livelihoods, and different forms of social conflict around competition over natural resources. They would also demand different institutional forms and capacities to manage this land use competition.

Agriculture continues to be a vital sector in each country (Ghana Statistical Service, 2008; UN Statistics Division, 2012). On the one hand it is the largest source of full or part-time employment for the rural population, though much of this is low paid employment (Reardon, Berdegué, & Escobar, 2001). Agriculture is also, in each country, an important source of export revenue. In Ghana, cocoa is still the country's most important commodity, all for export (Daviron & Gibbon, 2002). In Perú, the last twenty years have seen a transformation of agriculture – above all in the coast – and the sector is now a dynamic exporter of vegetables and fruits (Crabtree, 2002; Freund & Pierola, 2010). Meanwhile in the highlands, and notwithstanding the growing significance of off-farm income (Escobal, 2001; Reardon et al., 2001), agriculture continues to be a foundational source of security in rural livelihoods (Milan & Ho, 2013). The relationships among extractive industries, agriculture and rural livelihoods are contested in each country (Bebbington, 2012; Schueler, Kuemmerle, & Schroeder, 2011). This paper takes no *a priori* view on how far this relationship is synergistic or antagonistic. The emphasis is, instead, on visualizing some of the ways in which these two forms of land use relate to each other, exploring what can be visualized without having to depend on more expensive and harder to acquire forms of remotely sensed and field-generated data (Rogan & Chen, 2004). These visualizations focus on the geographies of concessions to conduct exploration and those of operations to extract resources, and their relationship to other geographies of agricultural land use, strategic natural resources, and human occupancy of space.

Why concessions?

Our focus on the geography of extractive industry concessions and lots merits some discussion. Importantly, the geographical extension of a concession is far greater than that of the immediate footprint of any final mining or hydrocarbon operation (Baynard, 2011; Hinojosa & Hennermann, 2012). For this reason the emphasis on concessions and their overlaps with other forms of land cover, use and governance might be deemed a methodological choice that will lead to an exaggerated statement of the potential effects of extractive industry. Indeed, we have observed some in the sector argue that an emphasis on concession maps is a deliberate means of overstating the adverse impacts of extractive industry. Furthermore, such maps say nothing about the potentially (though not always) positive impacts that the taxes and royalties generated by the extractive economy might have on poverty reduction and livelihoods (see Arellano-Yanguas, 2011; Ascher, 2012; Hinojosa, Bebbington, & Barrientos, 2012 for these sorts of impact).

Notwithstanding these concerns, a focus on the geographies of concessions has value, and we identify seven reasons for this. First, a concession constitutes a spatially explicit claim on natural resources. The claim is supported in law, and therefore the existence of a concession marks the overlapping of claims on the same piece of land. Even though a concession gives rights in the subsoil rather than the surface, it implies the exercise of a claim on surface land. Indeed, legislation exists to define the process through which concession holders can make such a claim and, if necessary, enforce it with expropriation or compulsory purchase. Second, when a concession or exploration block has been acquired by market actors, it signals a geographic area that the market thinks might be developable as a mine or hydrocarbon field. Even in those cases where investment in a concession is speculative, this investment still constitutes a market signal of what higher risk investment capital thinks might be developed. Third, prior to its acquisition as property, the demarcation of a block or concession by government authorities signals a geological projection of geographic areas that they feel might be developable: areas where very early geological data suggests that economically viable deposits *might* exist. Fourth, the existence of a concession – marking as it does a combination of property claims and market and geological projections - can change the dynamics of an area even in the absence of any operating mining, oil or gas project. In such areas, land markets may begin to act differently and speculatively, new people and organizations might begin to arrive (geologists, community relations teams, activists, NGOs …) and other changes may ensue. Fifth, the presence of concessions that overlap with prior forms of land use and control indicates the existence of public systems for planning and the allocation of rights that are capable of producing such overlaps and therefore, by implication, incapable of planning agricultural, water, forest, mineral, and hydrocarbon use in ways that are "joined up." This may be a coordination problem but it is just as likely to reflect that certain sectors, because of their political and economy priority and power, can grow without any significant consideration of other sectors. Sixth, for these and other reasons (including lack of prior consultation before granting concessions) the existence of a concession constitutes a new and significant source of uncertainty for rural residents who already live with much uncertainty in their production systems (especially when these systems are rain-dependent).

Finally, a decision to map only those areas that are directly affected by operations would clearly understate the area influenced by a mine or well. These operations become points that articulate new population movements, transport of inputs for and the products of extractive activity, externalities created by these movements and markets for certain inputs. Each of these new flows and activities affect areas that stretch far wider than the operation (Baynard, 2011; Latifovic, Fytas, Chen, & Paraszczak, 2005; Lynch, 2012; Schueler et al., 2011). While of course these wider influences are not necessarily congruent with the spatial boundaries of concessions, recent research in Ghana has shown that the land use impacts of surface mining extend well beyond the area of resource exploitation in ways that do, in fact, affect a large part of concessions (Schueler et al., 2011). Using a time series of maps created from satellite data for "the country's oldest surface mining area, the Wassa West District", this research concludes that 45% of the area of the concession had experienced substantial loss of farmland, and 58% had experienced deforestation. In Ecuador, Baynard, Ellis, and Davis (2012) quantified the relationship between infrastructure development related to hydrocarbon extraction and regional deforestation, and found that public-access roads were significantly correlated with increased agricultural land conversion at a 1 km resolution within four oil blocks, though the strength of this relationship decreased by half for roads that were limited-access.

Thus, while not an indicator of the direct, physical "footprint" of extractive industry, the concession can serve as a proxy indicator for the extent of social, institutional and cultural footprints of mining, oil and gas extraction. This paper explores the potential conflicts and relationships among different types of land use/land cover in areas affected by concessions, and provides insight into the implications for livelihoods.

Data and methods

National-scale visualizations of overlap between extractive industry, land use, and water resources are provided, as well as measurements of the areal extent of overlaps between territories of extraction and territories related to water, livelihoods and biodiversity conservation. The term "territories of extraction" is used to describe the geographic areas in which diffuse effects of extractive industries may be felt: operationalized here as the spatial extent of legally titled concessions where extractive activities (i.e., mineral and hydrocarbon extraction) are authorized by the state, as well as sub-watershed drainage areas located downstream from operational mines. Territories related to water, livelihoods and biodiversity include broad-scale river basins, areas of agricultural land use, and both natural and socio-cultural protected areas.

While the methods of analysis were identical for Perú and Ghana, the types of primary data available for each country differed substantially. These methodological differences must be understood when interpreting results that show shared patterns of competition or cooperative growth between these sectors and land uses. The following subsections detail the data products used for the measurement of spatial overlaps. The extent of spatial overlaps was measured for every combination of each territory of extraction, with each watershed or livelihood territory (Table 1).

Table 1
The 3 × 3 possible overlap combinations examined in Perú and Ghana, with data sources: INGEMMET, *Instituto Geológico Minero y Metalúrgico*; MCG, Mineral Commission of Ghana; WBI, World Bank Institute; GNPC, Ghana National Petroleum Corporation, MEM, *Ministerio de Energia y Minas*; IGN, *Intituto Geográfico Nacional;* SRTM, Shuttle Radar Topography Mission; FAO, Food and Agriculture Organization of the United Nations; WRCG, Water Resources Commission of Ghana; MDA, MacDonald Dettwiler and Associates; ESA, European Space Agency; IUCN, International Union for Conservation of Nature; UNEP, United Nations Environment Programme; IBC, *Instituto del Bien Común*.

Territories of extraction	Livelihood territories
A) Mineral concessions	1) River basins
Peru: INGEMMET	Peru: IGN
Ghana: MCG	Ghana: WRCG, SRTM
B) Hydrocarbon concessions	2) Agricultural land cover
Peru: PeruPetro	Peru: MDA Geocover LC
Ghana: WBI (GNPC)	Ghana: ESA GLOBCOVER
C) Mine drainage areas	3) Protected areas
Peru: MEM, IGN, SRTM	Peru: IUCN & UNEP, IBC
Ghana: Infomine, FAO, SRTM	Ghana: MCG

Territories of extraction

Concessions

Perú. Spatially referenced information on mineral concessions in Perú was obtained from the Peruvian government's *Instituto Geológico Minero y Metalúrgico* (INGEMMET), current as of February 2013. These vector polygon data include information about the year in which the concession was granted, the legislation authorizing the concession, the holder of the concession, and the permitted extractive activities within the concession. Spatially referenced hydrocarbon concession data were obtained from the Peruvian government's PeruPetro, the national hydrocarbons agency responsible for promoting the sector and managing contracts with oil and gas companies, and updated to February 2013. These data include information about the holder of the concession, and the permitted extractive activities within the concession.

Ghana. The location and extent of mineral concessions in Ghana was obtained from the Minerals Commission of Ghana, current as of July 2012. Concessions are of three types: reconnaissance licenses, prospecting licenses, and mining leases (Ayee, Soreide, Shukla, & Le, 2011; Bermudez-Lugo, 2010). Reconnaissance licenses are short term (one year or less, with an option to renew) that allow for aerial reconnaissance or field survey activities, but not drilling or excavation. Prospecting licenses are granted for a longer term (<3 years) than reconnaissance licenses, over a maximum area of 150 km^2, and allow for sub-surface investigation to determine the extent and value of mineral deposits. Mining leases permit extraction and are issued for thirty years with options to renew.

Spatially referenced hydrocarbon concessions for Ghana were obtained via the World Bank Institute (Duncan & Jarvis, 2012; WBI, 2012), and sourced from industry maps and data from the Ghana National Petroleum Corporation (GNPC, 2014). These data are current as of 2010 and include information about the year in which the hydrocarbon concession was granted, the holder of the concession, and the permitted extractive activities within the concession.

Mine Drainage Areas

In addition to analysis based on the spatial unit of the concession, the potential impact of actual mines on systems of drainage was examined. The process through which what we call *Mine Drainage Areas* were derived to parameterize the potential impact of operational mines ($N = 98$ for Perú, $N = 17$ for Ghana) on downstream riparian communities was identical for both Perú and Ghana. If an operational mine was located within 15 km of a river, that mine was linked to downstream areas that were located in close proximity to the same river, typically within 10 km.

Data from the Ministry of Energy and Mines in Perú show 98 mineral operations in 2012 located within 15 km of a river. Seventeen mineral operations were identified in Ghana in 2012 based on industry data (Infomine, 2013). River data were obtained from the *Instituto Geográfico Nacional* (IGN) for Perú, and from the Food and Agriculture Organization for Ghana (FAO, 2000).

Downstream drainage areas were formed by aggregating limited-extent sub-watersheds delineated from a 90 m resolution digital elevation model (DEM) obtained from the Shuttle Radar Topography Mission (SRTM; Farr et al., 2007). DEM grid cells were clustered into sub-watersheds on the basis of topographic relationships (Eastman, 2012). A minimum size of 500 km^2 was specified for the watersheds in order to capture areas in close proximity to discrete stream flows. In coastal areas, where local topography creates an abundance of relatively small extent basins that drain into the ocean, this threshold could not be met and a minimum size of 100 km^2 was used to identify additional sub-watersheds. For each mine, all downstream sub-watersheds were aggregated, and all areas of higher elevation than that of the mine were excluded. Finally the drainage areas for all mines were aggregated, to produce a single combined layer for each of Peru and Ghana.

River basins

Overlaps between extractive concessions and major river basins in Perú and Ghana were measured because of the integral connection between regional hydrology and resource inputs necessary to agricultural livelihoods (Mark, Bury, McKenzie, French, & Baraer, 2010; Mendoza, Granados, Geneletti, Pérez-Salicrup, & Salinas, 2011; Quintero et al., 2009). For Perú, broad-scale river basins (*cuencas)* delineated by the *Instituto Nacional de Recursos Naturales* (INRENA) in 2001 were used to measure the spatial overlap of territories of extraction with water resources. Each of 107 river basins was connected to a major river channel, and up to 4 major tributaries were identified. The areal extent of these tributary catchments, along with the interstitial areas, formed the extent of the river basin (Aguirre, Torres, & Ruiz, 2003). For Ghana, no primary, spatially-referenced data could be obtained for broad-scale river basins. The first-order DEM-derived sub-watersheds created to describe Mine Drainage Areas were aggregated to form the five primary basins identified by the Water Resources Commission of Ghana (WRCG, 2011), as well as a sixth basin to cover the catchment in close proximity to Lake Volta.

Agricultural land use

Perú

Agricultural land use is mapped for the year 2000 at 30 m resolution for Perú using GeoCover LC data (see Nelson & Robertson, 2007; Tullis et al., 2007), a 13-category classification of Landsat-5 Thematic Mapper imagery from the years 1999–2001 that is produced and distributed by MacDonald Dettwiler and Associates (MDA, 2013). Following supervised classification and map validation, speckle is reduced through a filtering of small-area patches with the same land cover, using a minimum mapping unit of 1.4 ha. This textural filtering is designed to remove artifacts of radiometric data noise and is unlikely to systematically affect detection accuracy for different cover types. The reported map accuracy for this product is 70%–96%, varying across categories and among 1° by 1° scenes. For our analysis, two GeoCover agricultural land cover categories (e.g., inundated agriculture, and general agriculture) were aggregated prior to calculation of spatial overlaps due to the relatively small extent of inundated agriculture within the study area.

Ghana

No fine-scale, categorically-rich land cover data were available for Ghana as recent as year 2000, and thus agricultural land is mapped at a 300 m using the GLOBCOVER 2009 product (Arino, Ramos Perez, Kalogirou, Defourny, & Achard, 2010), a spectro-temporal classification of multiple scenes from the European Space Agency's Medium Resolution Imaging Spectrometer (MERIS) acquired during the period 1st January 2009 to 31st December 2009. Although high levels of uncertainty and disagreement have been identified in association with comparative applications of coarse resolution, global land cover products (Fritz et al., 2011), these datasets have frequently been applied at broad scales in climate models or regional analyses (Havlík et al., 2011; Hurtt et al., 2011; Van Asselen & Verburg, 2012).

Additionally, the increasing within-pixel heterogeneity with respect to cover type that accompanies a coarsening of data spatial resolution (Foody & Cox, 1994) presents the opportunity to characterize impermanent agricultural systems of shifting cultivation in a way that is not possible using moderate or high resolution maps of land cover. The presence of three agricultural land use categories in Ghana: rainfed crops, mosaic cropland (50–70%)/vegetation (20–50%), and mosaic vegetation (50–70%)/cropland (20–50%) allows characterization of the intensive or extensive nature of cultivation. In locations of shifting cultivation, coarse resolution pixels of mosaic agriculture may remain robust characterizations of the land surface over time due to the fact that they obscure within-pixel spatial variability, such as that due to short-distance, interannual change in the area of cultivation. For our analysis, spatial overlaps were calculated separately for each of these agricultural land use categories, and using each category's range of portion cropland the minimum, maximum, and mean gross amounts of affected cropland were calculated and subsequently summed.

Interestingly, while agricultural land use could be parameterized with validity using GLOBCOVER 2009 data in many other locations, it is less authoritative for the case of Perú. Only 1–5 valid observations were available as inputs for GLOBCOVER mapping of Perú, compared to 31-100 such observations for Ghana, because the Medium Resolution Imaging Spectrometer (MERIS)- Full Resolution, Full Swath are not acquired systematically and western South America lies outside the areas of highest interest to the European Space Agency (ESA) (Arino et al., 2010; Bontemps et al., 2011).

Protected areas

Perú

Two broad types of protected lands in Perú were identified: those with the purpose of preserving ecosystem functioning and habitat in the face of threats from development or disturbance, and those designed to maintain the livelihood strategies and land tenure of indigenous communities. Natural protected areas include national parks and forest reserves as well as conservation concessions, each offering different degrees of protection to primary land cover and biodiversity (Young, 1998). Spatial data for these areas in year 2013 was obtained from the World Database on Protected Areas (WDPA), a joint project of the International Union for Conservation of Nature and the United Nations Environment Programme (IUCN & UNEP, 2013), and cross-referenced against official maps from Perú's Ministry of the Environment, *Ministerio del Ambiente* (MINAM, 2013).

Indigenous communities in Perú's Amazon basin have sought to receive legal title to land in order to secure land tenure, consolidate territory and implement sustainable or locally beneficial land management strategies (Benavides and Smith, 2000; Davis and Wali, 1994). Over the past decade, government and non-profit organizations (e.g., the *Instituto del Bien Común*) have sought to strengthen indigenous claims to land and territorial management through the creation of an official cadaster (Smith, Benavides, Pariona, & Tuesta, 2003). The Information System on Native Communities of the Peruvian Amazon (SICNA) contains geo-referenced and tabular data on over twelve hundred native communities, over 80% of all registered Amazonian communities (IBC & Benavides, 2010; IBC, 2014). In many cases, community boundaries were determined through cooperative GIS mapping between non-profits and indigenous communities, on the basis of population centers and livelihood activities. Additionally, territorial reserves of indigenous populations living in voluntary isolation were examined (Finer, Jenkins, Pimm, 2008; Orta-Martinez & Finer, 2010). The titled indigenous communities and territorial reserves together comprise about 17% of the Peruvian Amazon (IBC & Benavides, 2010). Unfortunately, the current institutional status of cadastral management and distribution of spatial data on the thousands of collectively titled Andean rural communities (see Norris, this issue) does not permit accurate analysis of overlaps between extraction and these communities. For estimation of spatial overlaps between territories of extraction and indigenous communities, lands titled as of 2014 were used in this study.

Ghana

As with Perú, the spatial extent of natural protected areas in Ghana was obtained from the WDPA (IUCN & UNEP, 2013), and was cross-referenced against year 2012 data from the Minerals Commission of Ghana. Cadastral land management and data distribution in Ghana (Alinon, 2004; Karikari, Stillwell, & Carver, 2005) did not allow for investigation of any socio-cultural areas in the analysis. Thus natural protected areas were the only type of protected area for which overlaps with extractive territories were measured in Ghana.

Results

River basins

Perú

Mineral concessions in Perú currently comprise a high percentage of the area of river basins in the coastal and Andean highland regions of Perú, while onshore hydrocarbon concessions are concentrated within the Amazon basin (Fig. 1). Most mineral concessions are for resource exploration, while few are the site of ongoing exploitation of mineral deposits: these latter areas comprise only 0.5% of the total area of all mineral concessions. Concessions allowing the exploitation of hydrocarbons comprise roughly 25% of the total *number* of hydrocarbon concession, yet are not spatially extensive and comprise only 6% of the total *area* of all hydrocarbon concessions.

An accelerating increase in the amount and area of mineral concessions is observed over the years 1992–2011. While during this period the Amazon basin is largely devoid of mineral concessions (with the primary exception of the Department of Madre de Díos: Asner et al., 2013), discrete river basins in the coastal and highland regions experience rapid, large gains in the proportion of their area overlapping with mineral concessions (Fig. 2). The river basins that had the highest percentage of their area overlap with mineral concessions were located in the south of Perú and fed into Lake Titicaca and the Pacific. The areas of seven river basins in the southern departments of Arequipa, Moquegua, or Puno were over 75% comprised of overlaps with mineral concessions in the year 2011. The areas of these seven basins: Atico, Cabanillas, Caraveli, Chala, Chaparra, Illpa, and Ilo-Moquegua, overlapped with mineral concessions at a rate of 7–30% in 2007, and 4–14% in 2002.

Although information on the date of hydrocarbon concession was available, the lifespan and spatial extent of hydrocarbon concessions in Perú have exhibited very high variability since the mid-20th century (Finer & Orta-Martínez, 2010). Due to the lack of georeferenced data on hydrocarbon concessions in Perú, no timeline showing changes in the portion of overlaps with river basins was constructed.

Ghana

The spatial distribution of mineral concessions relative to the six river basins that were examined in Ghana (Fig. 1) shows high concentration of reconnaissance areas, and mining leases, in only several basins. The Pra basin contains 47% of the total area granted as a mining lease, the Ankobra basin contains 30%, and the Tano basin 17%, whilst mining leases are nearly absent from the Densu, Volta, and White Volta basins. Over half of the total area of

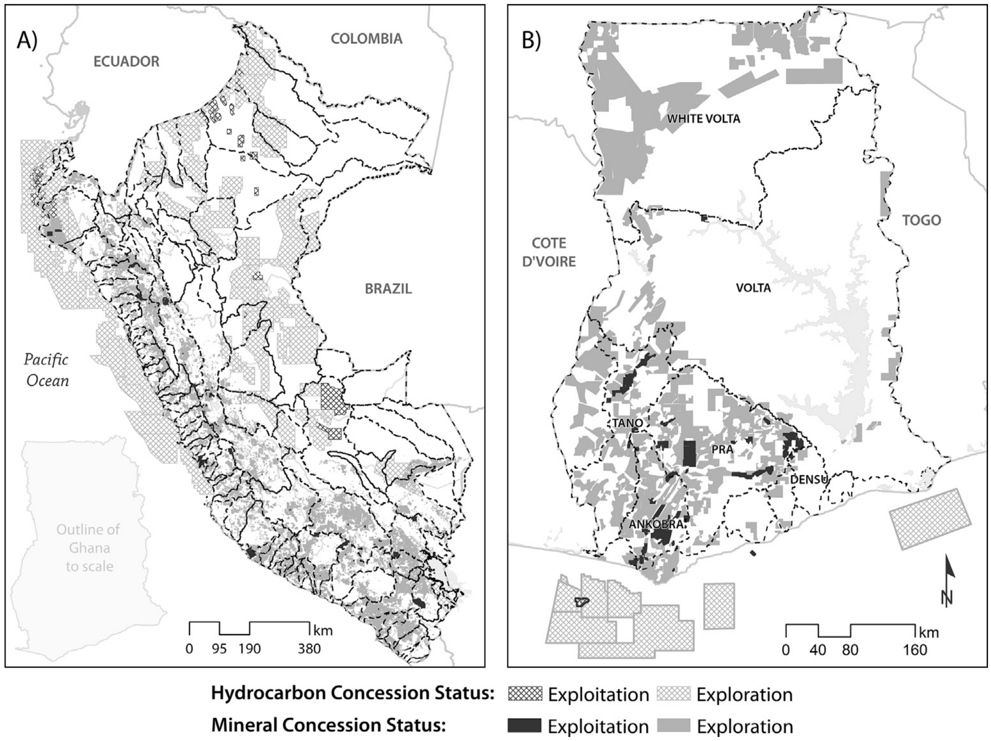

Fig. 1. Maps of overlap between extractive concessions and river basins in (A) Perú and (B) Ghana.

Reconnaissance Licenses was granted in the White Volta basin (58%) in the north of Ghana. The spatial distribution of Prospecting Licenses was less varied: although nearly absent from the small Densu basin in south-central Ghana, each of the five other basins contained between 11% and 28% of the total area of Prospecting Licenses. The basins that had the highest portion of their areas comprised of a mineral concession were the Ankobra (64%), Pra (50%), and Tano (47%), all located in the southwest of Ghana. The

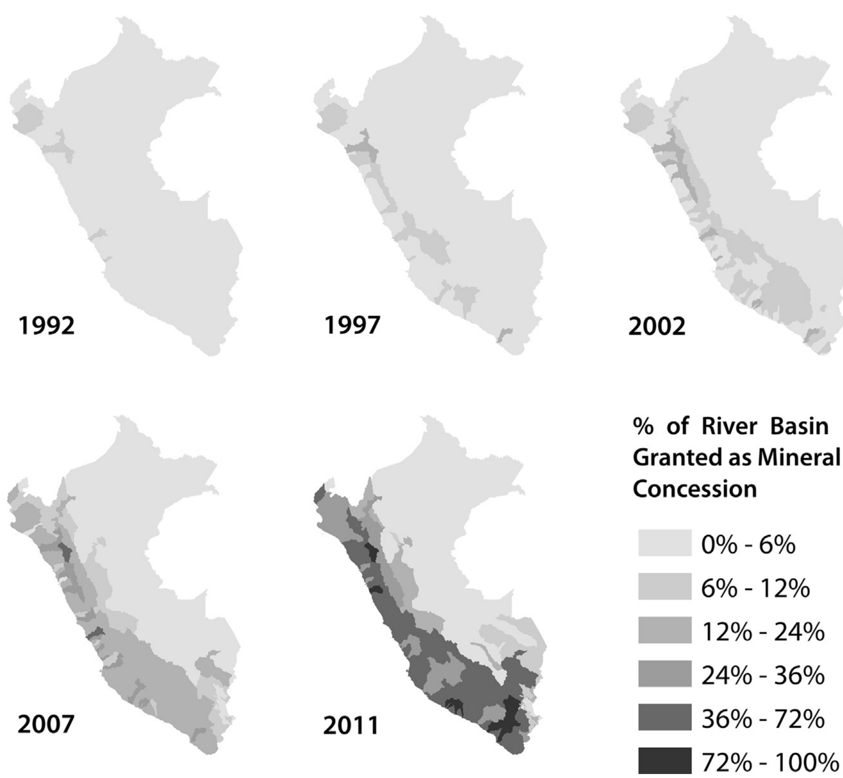

Fig. 2. Timeline of Mineral Concessions as a percentage of river basins in Perú from 1992 to 2011.

onshore portion of hydrocarbon concessions was relatively small, ~65 km^2, and did not substantially overlap with any of the large river basins examined.

Agricultural land use

Perú

Croplands are distributed widely across Perú (Fig. 3), closely tracking river channels in the arid coastal region, while being more extensive in highland areas. Mineral concessions cover 19% of the total area of observed agricultural land use in Perú. Seventeen percent of total observed agricultural land is located within a hydrocarbon concession in which exploratory operations are permitted, while only 2% of croplands are located within a hydrocarbon concession in which oil or gas extraction is occurring (Table 2). As the areas of mineral and hydrocarbon extraction only very rarely overlap in Perú, these findings suggest that between 35 and 40% of all agricultural land overlaps with one or other form of extractive concession. As a separate indicator of overlap, if all of the Mine Drainage Areas are aggregated, 27% of all agricultural land is affected.

Ghana

Agricultural land in Ghana is concentrated in the southwest region, roughly defined by the Ankobra, Pra, and Tano basins, and exhibits high amounts of spatial overlap with territories of extraction (Table 2; Fig. 3). Exploratory mineral concessions (i.e., Reconnaissance and Prospecting Licenses) overlapped with 47% of the area classified as un-mixed croplands, while no actual mining was observed to overlap with this land cover class. Mineral exploration was permitted on 25% of the first mosaic agricultural land cover class (50–70% croplands), but exploitative Mining leases for actual extraction of minerals covered only a tiny fraction, less than 1%. The second mosaic agricultural land cover class (30–50% croplands) was the most spatially extensive of the three agricultural classes examined. Mineral exploration concessions overlapped with 39% of this class's extent, while leases for mining itself affected 5%. Furthermore, 87% of the total area covered by Mining Leases, and 70% of the total area of Prospecting Licenses, overlapped spatially with the 30–50% mosaic agricultural land cover class. Put another way, only small percentages of areas leased for some sort of mineral activity were *not* given in areas with some agricultural land cover. As a separate indicator of overlap, if all of the Mine Drainage Areas are aggregated, 24% of mosaic (30–50% croplands) land use is affected.

Protected areas

Perú

The majority of natural protected areas were spatially concentrated in the Amazon basin, often in close proximity to titled indigenous communities and reserves for indigenous communities living in voluntary isolation (Fig. 4). Titled indigenous communities never overlapped with natural protected areas, but some instances of overlap occur between natural protected areas and reserves for indigenous communities in voluntary isolation. (Note that while highland communities are often of indigenous peoples, legally they are not titled as indigenous communities and so are not included in this analysis. Some sources in Perú estimate that a half of all highland communities are affected by mining concessions).

Mineral concessions exhibited only slight overlaps with all types of protected areas: only 1% of natural protected areas and titled indigenous communities overlapped with a mineral concession, and no overlaps between mineral concessions and reserves for indigenous people in isolation were observed (Table 2). Ten percent of natural protected areas overlapped with exploratory hydrocarbon concessions, though only very small overlaps were observed with concessions for actual hydrocarbon exploitation. A larger

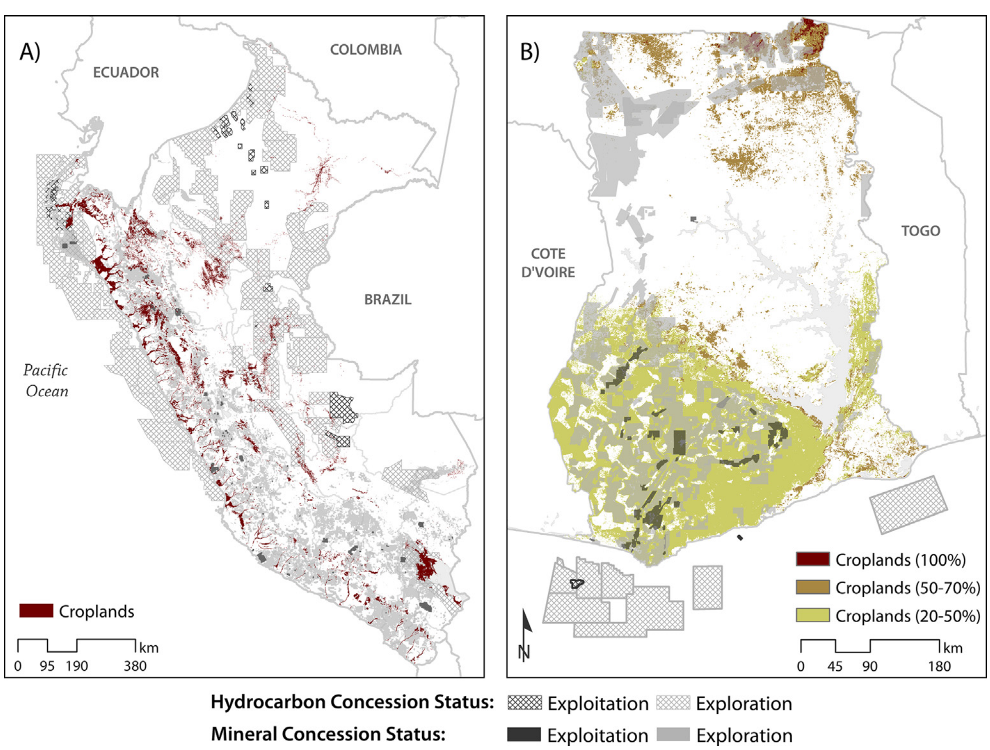

Fig. 3. Maps of overlap between extractive concessions and agricultural land use in (A) Perú and (B) Ghana.

Table 2
Total size of territories examined, and overlaps measured as a percentage of the total area of agricultural land use or protected areas (column totals).

		Total area (km^2)	Agricultural land use				Protected areas			
			Peru	Ghana			Peru			Ghana
			Croplands	Rainfed	Mosaic (50–70% crops)	Mosaic (20–50% crops)	Natural P.A.	Titled indig.	Indig. V.I.	Forest reserve
			21,443	994	16,976	67,292	261,645	118,605	29,239	31,518
Mineral concessions										
Peru	Titled (all)	213,717	19				1	1	0	
Ghana	Recon	26,821		41	20	13				0
	Prospecting	25,119		6	5	26				1
	Mining	3889		0	0	5				1
H.C. concession										
Peru	Exploration	323,271	17				10	35	1	
	Exploitation	21,167	2				0	2	4	
Ghana	Onshore	658		0	0	0				0
Mine drainage area										
Peru	–	251,123	27				8	16	0	
Ghana	–	19,017		0	0	24				13

portion of titled indigenous communities overlapped with exploratory hydrocarbon concessions (35%), and 2% of the area titled to these communities was overlapped by concessions for hydrocarbon exploitation. Although only 1% of reserves for indigenous people living in voluntary isolation were affected by concessions for hydrocarbon exploration, a higher percentage (4%) of these reserves has been designated as concessions for exploitation (see below for how and why these data differ from previously published results). Mine Drainage Areas comprised 8% of the area of natural protected areas, 16% of the total area of titled indigenous communities, and 0% of reserves for indigenous people in isolation (Fig. 5).

Ghana

Forest reserves in Ghana are spatially concentrated in the southwest, although a few, large-area protected areas are located in the north and east (Fig. 4). Spatial overlaps between protected areas and mineral concessions were small: the total area of overlaps for all concession types combined was less than 2% of the total extent of protected areas (Table 2). No spatial overlaps are observed between hydrocarbon concessions and protected areas (this is because nearly all hydrocarbon concessions are offshore). The percent of the spatial extent of protected areas that falls within Mine Drainage Areas is 13% (Fig. 5).

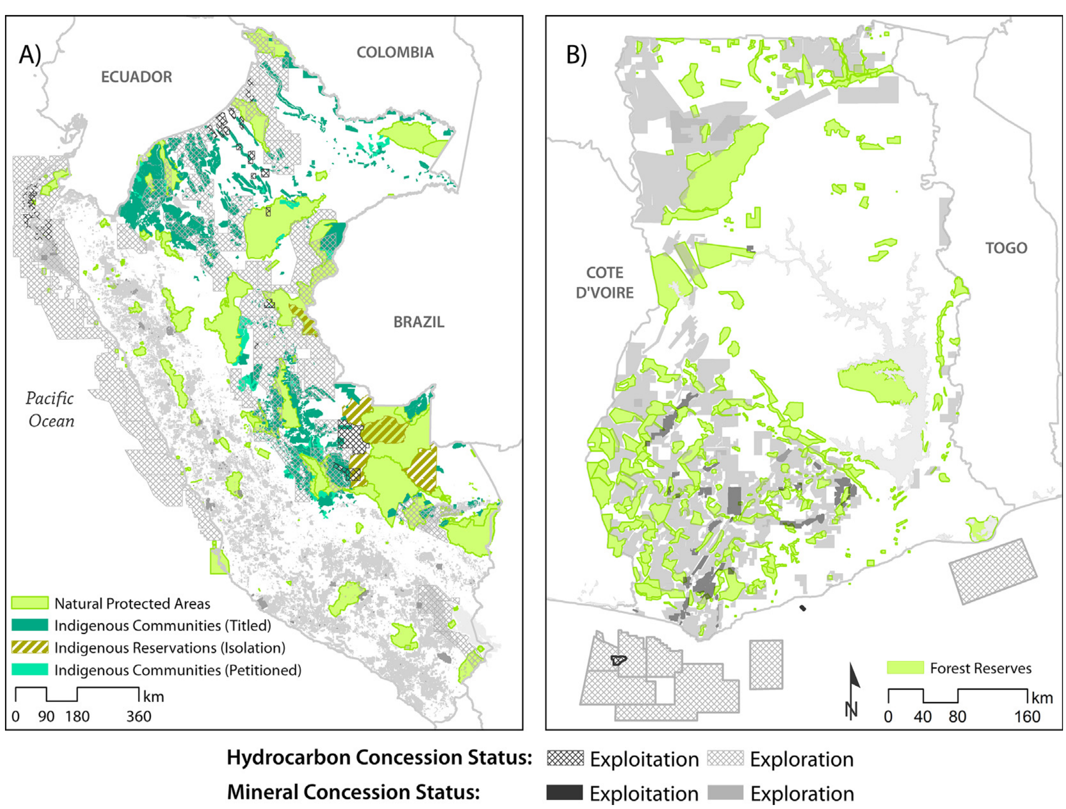

Fig. 4. Maps of overlap between extractive concessions and protected land use types in (A) Perú and (B) Ghana.

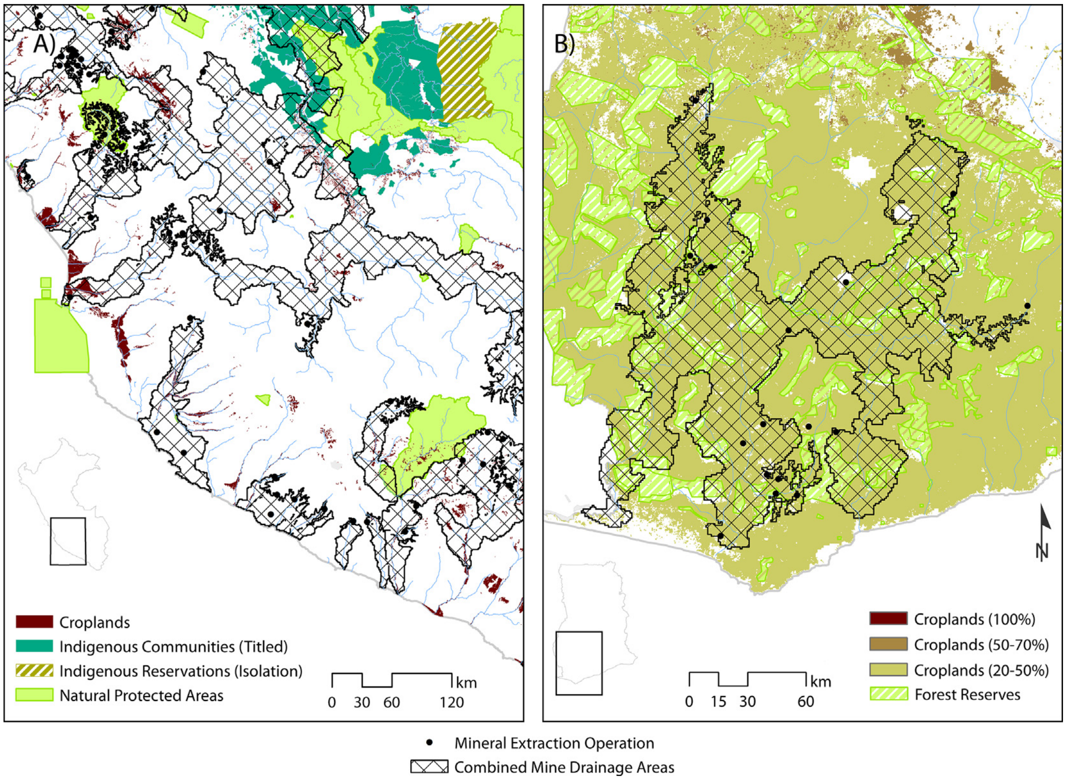

Fig. 5. Mine Drainage Areas for portions of (A) Peru and (B) Ghana, shown with protected areas and agricultural land use.

Discussion and Conclusions

The arrival of any new economic activity or powerful actor in a landscape generates new risks and increases uncertainty regarding the implications for existing lives and livelihoods, whether it will improve them or undermine them and whether change will be profound or marginal. Residents in an area under concession do not know what form a project might take, nor whether it will have implications for their water resources, the value of their land, or their family's future work and educational opportunities. Concession maps can therefore be understood as mapping geographies of *risk* and *uncertainty* for a range of stakeholders, and making certain dimensions of these risks and uncertainties more concrete. Concession maps illustrate areas where extractive activity might occur, and where exploration and related activities are more likely to occur. As such, concession maps reflect geographies of possible change in patterns of access to the land and water resources on which livelihoods depend.

Figs. 1–4 reveal widespread overlaps between the claims of extractive industry and the geographies of natural resources upon which other economic activities and forms of social organization are based. Overlaps with the land base of agriculture are extensive: mining and hydrocarbon concessions cover 38% of total agricultural land use in Perú, and 39% in Ghana. This is significant given that both countries (especially Perú) face significant constraints in extending the agricultural frontier because of constraints on water resources (Bury et al., 2013; French & Bury, 2009). Indeed, overlaps with the hydrological base of agriculture are also significant and growing, and as a consequence water resources have become a central theme in negotiation and agreements between extractive enterprises and communities (Arellano-Yanguas, 2012; Bebbington, Humphreys Bebbington, & Bury, 2010). Conversely, overlaps with natural protected areas are very limited, in both countries, although in Peru most non-disturbed forest in the Amazon basin is, or has been, under hydrocarbon concession at some point in recent decades (Finer & Orta-Martinez, 2010).

These patterns throw light on the ways in which planning systems are operating in each country. On the one hand, they imply that the system for planning and governing the boundaries and integrity of protected areas has been moderately resilient in the face of extractive industry (but see Finer, Jenkins, Keane, 2008): only very limited overlaps are observed in Perú between areas of hydrocarbon exploration and territorial reserves for indigenous people living in voluntary isolation (1% of total reserve area). These observations contrast sharply with those of Orta-Martinez and Finer (2010) who observed that 42% of indigenous territorial reserves were covered by hydrocarbon concessions in 2009. This marked difference in measured overlaps reflects the relative rapidity with which the boundaries of hydrocarbon concessions have changed during recent cycles of auctioning and project development in Peru (Orta-Martinez and Finer, 2010; PeruPetro, 2014). The large reduction in the area of reserves under concessions (when comparing our results and those of earlier studies) suggests that as companies develop their projects, they might be giving up those parts of their concessions in which indigenous groups have territorial claims. Interesting, however, is the fact that a greater portion of indigenous territorial reserves are covered by hydrocarbon extraction concessions (4% of total area) than are covered by exploration concessions (1% of total area), due to the location and extent of “Lote 88” of the Camisea gas project. All the other land use categories examined are much more likely to be covered by exploration concessions, and indeed the total area of exploration concessions far exceeds that of exploitation concessions. This suggests that although consideration of indigenous territorial claims may lead companies to give up concessions when those areas have not revealed significant oil or gas deposits, once significant deposits are encountered, institutions for protecting indigenous people's rights may have very little effect in the face of company and government pressure to drill. There appears to be both a similarity and contrast with protected areas in this regard. Thus, while in Peru there have been efforts to reduce the extent, or weaken the status, of national parks in areas of known hydrocarbon deposits, these attempts have so far been resisted with relative success as a result of public debate and pressure.

Conversely, the extent of overlap with water resources, agricultural land use, and titled Amazonian indigenous territories suggests the absence or weakness of any planning system to reduce conflicts, and enhance possible synergies, between extraction and these forms of land use, land cover, and land governance. This reflects, presumably, the relative weakness of legislation in these sectors, the power of companies and ministries of energy and mines, and the weaker organization of civil society around these sectors. This is perhaps most striking in regard to water resources. Both Perú and Ghana – though especially Perú – suffer water constraints on their agricultural potential as well as on the quality of urban growth, and these hydrological constraints are forecast to become more serious in the future as the size of Andean glaciers diminish (Bury et al., 2013). Where water is a particularly scarce development resource, *in principle* one would expect the existence of well-designed and strong systems for its allocation. Yet Figs. 1–2 show not only *extensive* overlaps between concessions and water resources in water-constrained regions of Perú, but also *increasing overlaps* over the course of time.

Where these different geographies overlap, the *potential* competition for resources is not only between land *uses*: it is also among land *users*. Different land users will potentially seek access to the same land and water resources in pursuit of the land uses that they prioritize, though the geographic scales at which these preferred uses may vary tremendously, from the international mining interests to isolated indigenous communities. These overlaps thus identify areas in which the expansion of extractive industries might threaten pre-existing land and water dependent livelihoods. This suggests that such areas are also likely to be zones of potential conflict when settlements that resolve competition over resources are not negotiated (Bebbington, 2012).

Conflicts over land use reflect struggles among different actors to gain access to and control of different resources, and are mediated by the operation of certain institutions. These include both the actual institutions of property (that confer rights in land, rights in the subsoil and rights in water) as well as those institutions through which such property is allocated. The work presented here has focused on one set of these institutions – those which confer and distribute certain property rights in the subsoil. We have sought to show that, on the basis of relatively accessible data, it is possible to map these rights in the subsoil, and identify actual and potential interactions with other institutions and resources that are critical for livelihoods, agriculture, and conservation as well as for indigenous people's access to resources. The results point to the feasibility and value, but also the complexity, of mapping overlays among concessions and a range of other rights and resources. These maps help identify potential geographies of risk and conflict. They should, however, be seen as a first stage in such analysis and, where resources are available, should be complemented with more advanced analysis based on remotely sensed data and, especially, field research. Field research can illuminate how these overlaps are being experienced, how conflicts are being interpreted and how resources are actually being affected. Likewise, analysis of the actual functioning of regulatory institutions, and the processes of allocating rights and contesting overlapping claims within the apparatus of government will also be essential to understand how far different institutions are actually resilient (or not) in the face of the expansion of extractive industry. Meanwhile, finer grained and data intensive remote sensing analysis can track the co-development of and interplay between extractive industries and other land uses in a landscape over time (Kennedy, Yang & Cohen, 2010; Zhu, Woodcock, & Olofsson, 2012).

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