Clandestine political economic activity in landscape dynamics- linking pattern to process

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I. Beyond Socializing the pixel/pixelizing the social for clandestine transactions

In a world of globally teleconnected financial markets where large amounts of capital transfers mediate population-environment relationships in unexpected ways (Galaz et al. 2015) a new emphasis is needed beyond the pixelizing/socializing dichotomy. In particular, understanding the role of clandestine political and economic exchanges, those that reside outside formal rules or governance or violate informal norms (North 1990; Helmke and Levitsky 2004), in land use change will require both leveraging social science insights (from political science, political ecology, new institutional economics) regarding how capital operates in land systems with land systems science (LSS) insights to quantify landscape patterns. This paper reviews progress made since *People and Pixels* and the potential to understand political and economic illicit activity at land scape scales, provides a conceptual framework to link clandestine transactions to landscape patterns, and provides an empirical example of doing so to study narco deforestation.

Twenty years ago in *People and Pixels* Geoghegan et al (1998) outlined efforts to "pixelize the social" by aggregating pixel observations of land change to the "scale" of social data (often surveys and census) to understand drivers of change or conversely "socialize the pixel" by using pixel information to infer social behavior or process, sometimes leveraging it to model land change processes (through Markovian modeling, for example (Shafizadeh Moghadam and Helbich 2013)). In the decades that followed, much of the research agenda of People and Pixels was taken up by Land Systems Science, (LSS), a research community that aims to observe change, understand the cause, develop spatially explicit models, and assess the vulnerability, resilience, and sustainability outcomes (Turner II et al. 2007). Yet most progress has only been made in "pixeling the social" for two main reasons: i) the post-positivist orientation of Land System Science, and ii) advances in pixel-based and biophysical data far outpacing social data. LSS has tended to use quantitative approaches and hypothesis testing to understand the timing, location, causes, and consequences of land use and land cover change. The outcomes of theses analyses are used to revise or build theory. For example following earlier work in cultural ecology, LSS has examined structure and agency, with innovative approaches combining remote sensing with household survey data (Chowdhury and Turner 2006), and using regression modeling techniques to test theory across scales (Laney 2002). Pixelizing social data has been a useful approach with the post-positivist epistemological orientation that phenomena can be mostly understood through observation and data collection. This orientation recognizes that full objectivity is not possible, and limitations and biases that arise should at a minimum be explicitly recognized and at best make use of qualitative data to understand the implications. LSS has subsequently leaned on mainly quantitative methods that involve pixelizing social data.

Advances in pixel-based data since 1998 are impressive in terms of spatial and temporal resolution, types of sensors, and increased availability. Since NASA opened the Landsat archive in 2008, other space agencies have followed suit (e.g. ESA and Sentinel), making data open access, free, and even developing tools and significant amounts of funding to encourage its use. New technology and computing has allowed researchers to mine the satellite record and create dense annual, monthly, weekly, and even near daily time series of changes in forest (Hansen et al. 2013) and water (Pekel et al. 2016) at 30m resolutions globally. New commercial microsatellites, such as Planet, allow research to assess change at daily 3-5 meter resolution on a near daily basis, even in remote regions of the Artic (Cooley et al. 2017).

Thus, people and pixel relationships that were previously understood in terms of aggregate changes in coarse 5 or 10 year intervals can be now be evaluated annually, globally. These dense time series over large spatial scales fosters econometric methods that allow for stronger causal inference over longitudinal panels to yield insights regarding deforestation and land tenure changes (Blackman et al. 2017) deforestation and soy moratoriums Arima et al 2011), grassland degradation and the US conservation reserve program (Sylvester et al. 2016), and urban change with foreign direct investment (Seto and Kaufmann 2003). The temporal relationships that can be investigated with new "analysis ready" data, especially to understand the role of illicit economies on environmental change, has yet to occur.

Social data has not advanced, until very recently, at the same pace as pixel based biophysical data, and is seldom analysis ready. While data mining of social media and cell phone data represents innovations to some degree, this data is noisy and unrepresentative of populations, because not everyone has access to and makes use of this technology. Recent attempts to "socialize the pixel," such as poverty mapping initiatives (Watmough et al. 2016; Jean et al. 2016), find pixel based patterns that indicate social conditions with relatively high accuracy. Yet, these machine learning based methods throw social theory into a "black box," and the high predictability of poverty may not have accessible theoretical explanations, or even more problematic, implications. Thus, results from these new methods to socialize the pixel may be limited in their ability to advance theory about human environment relationships.

Social science disciplines such as Political Ecology have excelled at explaining the process and mechanisms of how and why land use changes including the role of clandestine and illegal activity. Examples include deforestation in Southeast Asia (Forest Watch Indonesia et al. 2002; Ravenel et al. 2005), land "grabs" for export agriculture in the developing world (Ruilli et al. 2012; Wolford et al. 2013; Le Billon and Sommerville 2016), urbanization and infrastructure development (Leitmann and Baharoglu 1998; Weinstein 2008; Baskaran et al. 2015; Henderson et al. 2016), and agricultural development for revenue generation by terrorist groups like ISIS (Jaafar and Woertz 2016). Much of this research has largely been based on observational narratives; few, if any, quantitative studies on the role of these activities exist (but see (Ruilli et al. 2012; Jaafar and Woertz 2016). Most of these explanations are often limited to one site and difficult to make claims generalizable at landscape scales (Turner and Robbins 2008). The research intent of these studies, qualitative methods employed, or focus of power as a central phenomena of study means they do not "socialize" the pixel, or attempt to inferring social science from landscape patterns. Yet to understand illicit activity linking pattern with process is key.

Those typically “pixeling the social,” – land change scientists- identify political and economic power in the form of corruption as an important contextual factor (Lambin et al. 2001; Rudel et al. 2005), but these factors have yet to be placed as a primary research question, let alone into land projection models. Thus, a paucity of data, research risks, and epistemological and methodological divides between those “pixeling” and “socializing” may have precluded researchers from formally modeling clandestine activity. Yet by failing to account for these kinds of drivers in landscape scale model, we miss understanding how and where large amounts of illicit capital finance and distort land governance and land use regulation.

People and Pixels set a research agenda that made considerable progress on understanding land change through the motivations of *land users*, often at a household scale. This focus lends itself to understanding “small-time” illicitness measurable at this unit of analysis, such as poaching or rule-breaking, which influences environmental systems to some degree (e.g. Robbins et al 2009). However, this very local focus misses the role of informal institutions led by actors with considerable power that shape land systems. “Illicit” activity may leave its trace on the landscape in ways that can be measured by understanding the unique patterns it creates that are *different* than the patterns created by thousands of households engaging in traditional socioeconomic behavior.

An emphasis on “pixelizing” social data to the “finest” possible scale as a starting point can cause hyper focus on proximate causes of land change. A deeper understanding of distal causes, may be achieved either by analyzing a “coarser” unit of analysis and developing spatial structure of relationships through networks or weight matrices. For example, while building roads and increasing population pressure may be proximate causes of Amazonian deforestation at the “pixel” level, indirect drivers of land change, like global beef demand or national soy moratoriums, may be best measured at another scale of analysis, such as municipal districts in a linked spatial structure (Arima et al. 2011). In this example, new pasture frontiers in the Amazon may be linked to displaced pasture in from other non-frontier municipalities. New human-environment relationships or modification of past theory may be revealed as the researcher can “zoom out” from the pixel and examine empirically how landscape pattern may link to distal processes thanks to advancements in computing power and increasingly open or accessible data on political and economic transactions.

As financial data leaks from the “Panama” and “Paradise” papers are better studied for example, new relationships between tax havens and available capital for illegal deforestation in Indonesia are revealed (Alecci 2017). Understanding these relationships is not about choosing the “right” level of *aggregation* to combine social and pixel data- but rather the appropriate *linkages* between units operating at the same scale. The teleconnection literature is making headway in addressing both conceptual and methodological challenges in this regard (Yu et al 2015 (Eakin et al. 2014; Munroe et al. 2014)) but applications to illicit activity have yet to emerge. Advances have been made to linking economic data such as GDP growth, prices of land and commodities, and development indices (Irwin and Geoghegan 2001; Seto and Kaufman 2003; Lambin and Meyfroidt 2010) or institutional data regarding tenure or governance rules (Ostrom and Nagendra 2006; Wright et al. 2016; Blackman et al. 2017) by aggregating area and types of land use changes to political and economic geographical units. However, social data to understand illicit activity may not be so straightforward to “pixelize” as traditional data in the above examples on socio-economic systems, because it is not found in surveys, census, government records in straightforward ways.

Both new social data-from wikileaks, the Panama papers, cellphones, and crime data available through transparency laws- as well as more creative uses of long existing social data - voting records, municipal budgets, corporate financial information, zoning regulation changes, city nuisance complaints (Rodriguez Lopez et al. 2017) , trade and commodity flows, utility bills, and media content analysis can represent clandestine activity. However, a strong understanding of the mechanism of illicit activity involved and land change observed is required to develop proxy data that indicates the presence of clandestine transactions over time and space. This difficult task calls for even more interdisciplinary collaboration between land change scientists and political ecologists.

The combination of increasing temporal and *spatial* resolution of "analysis ready" pixel datasets together with improved access to data to directly measure or serve as proxy for illicit activity can aid the study of clandestine transactions and landscape dynamics. High spatio-temporal resolution of pixels allows the researcher to define distinct "objects", such as reservoirs, individual agricultural parcels and sizes, patches of forest, mines, or housing developments, and analyze the pattern and landscape architecture (Turner et al. 2013) which they produce. Aggregating pixels to objects, extracting appropriate variables that describes the patterns such objects produce, summarizing the pattern at the (often coarse) spatial scale at which clandestine activity can be meaningfully detected given measurement uncertainty, and finally statistically *relating* the landscape pattern to the social data is the new frontier that must be developed to understand illicit activity at landscape scale. This paper provides a conceptual framework to link clandestine transaction to landscape patterns, and provides an empirical example of doing so to study narco deforestation.

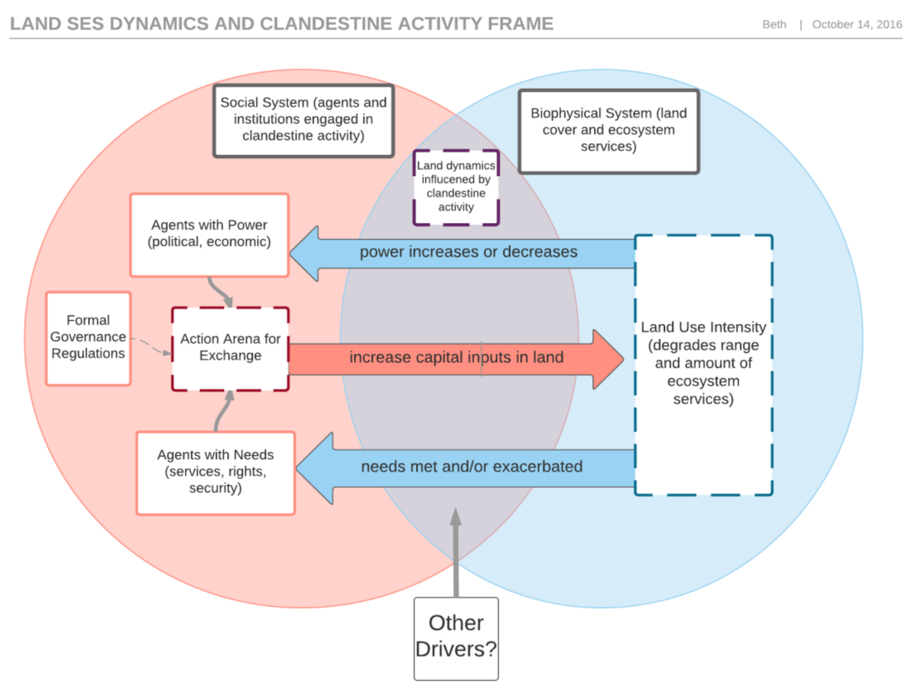

FIGURE 1 Phenomena and processes studied to understand clandestine activity in the Land SES. Author's own, inspired by Turner et al (2007) and Ostrom (2011)

I. Conceptual framework to study clandestine transactions and landscape dynamics

This conceptual framework focuses on land dynamics that occur as a result of these clandestine activity, which is only one of many potential drivers of land-use intensity and land use and cover changes. Clandestine activity that changes land use is a result of exchanges between agents with power and agents with needs, shaped by existing formal governance regulations. The agent with power possess political, economic, or informational capital, while the agent with needs requires services (such as water), rights (such as land titles), or security (protection from violence if the agent with power uses violence to enforce the contract). The agents bring needs and power to the action arena that defines the incentives, positions, and payoffs for each. One potential outcome of this interaction is an increase in capital inputs in land (see figure 1).

Formal governance regulations (e.g. the State) play an important role in shaping the action arena. In a socially democratic society, basic agents' needs are guaranteed by the state as a social contract to govern (Rousseau 1762). Agents with needs may express their unfulfilled demands to the government, by mobilizing their political capital to protest or cast votes in an election. In principle, the State responds and develops new programs to deliver services. If this fails, citizens become agents with needs and may seek informal mechanisms to gain access to basic human rights.

For example, government quotas regarding land uses may increase scarcity (e.g., laws against deforestation or urbanization), and these land rents could be captured by agents with power to provide access to that land and earn a large payoff. Overly bureaucratic regulations by the state could increase the transaction costs to the degree that agents with needs can fulfill needs more efficiently via exchanges with agents with power outside formal channels. In general, weak formal governance institutions that lack transparency and feedback mechanisms between the State and its citizens via participation and transparent elections can also shape the action situation in ways that are favorable for clandestine activity.

The exchange in clandestine activity can have an impact on the biophysical system because it can induce land-use changes that increase land-use intensity (red arrow to blue dotted box). My definition of land-use intensity is similar to that for agricultural intensification (see Brookfield 1972; Lambin, Rounsevell, and Geist 2000; Turner and Doolittle 1978)— as exchanging inputs of capital, labor and skills to increase something, in this case profit, from a given area of land. In general, increasing capital inputs to increase profits from land will also degrade the range and amount of ecosystem services land provides, however this is not always the case. Capital can be used to convert land from industrial agriculture to silvo-pastoral uses and result in an increase in ecosystem services if animal loads are managed appropriately (Amézquita et al. 2004).

For example, in agricultural frontiers, illegal sales of indigenous land can result in forest conversion to pasture land. Money laundering of drug profits that is invested in forestland in the Mesoamerican biological corridor generates a change in land use from forest to palm oil plantation or a cattle ranch (McSweeney et al. 2017). Increases in land use intensity adds value (usually economic but sometimes political) to land. Agents with power can not only change land use intensity at faster *rates* than other actors, especially agents with needs, but also can gain access to change land use intensity in difficult to access areas through investments in economic capital (building new roads), leverage political capital (pay offs to regulators to avoid eviction or consequences), or use violence. This will likely create unique landscape signatures that can be measured by anomalous land changes in rate, shape, or absolute/relative location that may stand out from *other* types of land changes caused by an aggregate behavior of many small actors with less capital.

The biophysical system changes can feedback onto the social system by increasing or decreasing power or needs for respective agents (blue dotted box to blue arrows). For example, once forested land is converted to cattle or oil palm, it is easier for the agent with power (like a narco trafficker) to launder money by registering a business with false profits. This may increase the power or economic capital of the trafficker, further increasing the power differential between the agent with power and the agents with need, who may be coerced into making additional land exchanges to avoid experiencing violence.

II. Relating land pattern to illicit process in Narcodeforestation

One example of relating land patterns to illicit activity at landscape scales is by examining narcotrafficking and deforestation in Central America. Deforestation rates have broadly experienced a slowdown (Graesser et al. 2015), and in fact reforestation outpaces deforestation rates in all Central American counties (Hecht and Saatchi 2007). However, this is because moist tropical forest is being lost while industrial, timber, palm oil, and secondary dry tropical forest is gained (Redo et al. 2012; Aide et al. 2013). Deforestation rates for moist tropical forest remain high in Guatemala, Nicaragua, and Honduras (Armenteras et al. 2017; Schlesinger et al. 2017). Researchers with a long history of social science engagement in the region began to notice over the past decade new patterns of large, rapid, forest clearing in remote protected and indigenous areas (Grandia 2013; McSweeney et al. 2014; Mcsweeney et al. 2017). These patterns of deforestation were hypothesized, theorized, and observed to be linked to narco trafficking activities. Traffickers acquire and transform land as sites to logistically move cocaine through Central America, launder $6 billion per year in profits through cattle, oil palm, and other land based activities, gain rights to frontier spaces by clearing forested areas to lay claim to territory, and build lasting political and economic capital through land (see McSweeney et al. (2017) for a full theorization).

The hypothesis that large, rapid forest clearings could represent a signature of narco deforestation was tested by establishing variables to measure these characteristics using a ready to analyze Hansen Forest Loss data set (Hansen et al. 2013a). Sesnie et al (2017) developed spatial and temporal pattern metrics for patches of forest loss for each country in Central America, and used a clustering algorithm to identify statistically "unique" groups of deforestation. We found this "anomalous" deforestation in several departments (sub national units) of Nicaragua, Honduras, and Guatemala were significantly correlated to cocaine flow data. Yet more stringent tests (BACI- Before After Control Impact (Conquest 2000)) revealed that only in Honduras was the increase in these anomalous patterns significant post 2005- the date cocaine transit dramatically shifted away from the Caribbean and into Central America. This shift was due to increased interdiction in Mexico and in Caribbean around 2006. Sesnie et al (2017) suggested that as much as 15-30% of deforestation- represented by these anomalous patterns appearing after this data- could be linked to drug trafficking.

The research team continues to make headway to better quantify and theorize the role of cocaine in transforming rural landscapes - dubbed Landscapes in Transition, Central America- is now digging deeper into these relationships. Social scientists on the team aid in the development of appropriate proxies to include narcotrafficking variables in both fixed effects panel econometric methods and agent based models to quantify the role of the cocaine value change in comparison to or as an acceleration of conventional drivers of land change in the region (Tellman et al and Magliocca et al, ongoing research). This requires creative data collection and methodological techniques including spatializing media content analysis, systematizing spatio-temporal ethnographic knowledge, digitizing government records regarding environmental crimes, analysis of trafficking networks, illicit commodity chain analysis from sparse data, and more, to develop empirical evidence to quantify the intensity and location of cocaine trafficking over time in Central America. All data is a valuable, yet partial, piece of a puzzle that does not lend itself to traditional methods employed to examine human-environmental relationships. The high degree of uncertainty in spatial and temporal measurement and extreme non-stationarity of drug trafficking challenges this work but has the potential to push forward both theoretical and methodological frontiers of linking landscape patterns to illicit processes. The methods developed here may be useful in understanding the role of illicit economies in other cocaine transit zones- Guinea Bissau has become a transit zone for cocaine in Africa and has experienced high deforestation over the last decade. This work may also challenge conventional theory about land change processes- do frontier spaces deforest because of a combination of population change, infrastructure development, or increasing agricultural export markets? When do other types of clandestine capital (political or economic) influence land speculation and development that may accelerate or drive the direction of the agricultural frontier? I posit that answering this question requires new methodological developments far beyond "socializing the pixel/pixelizing the social."

III. Towards a research agenda and a political land change science

Narcotrafficking and the cocaine economy is far from the only type of illicit economy or clandestine transaction influencing large scale landscape changes. Land grabs, informal urbanization, payoffs to regulators to change land zoning rules or even land tenure, infrastructure placement decisions make through kickbacks, and many other types of clandestine transactions remain an unmeasured, but not immeasurable, influence on land systems and human-environmental dynamics. The increase in both human and remote sensors, the computing power capable of separating the signal from the noise in ready to analyze time series, and an increasing culture of data access and transparency provide fertile ground to make the previously unexamined or heretofore undetectable landscape signatures of clandestine transactions to light. Explicitly examining how the agency of clandestine actors shape the landscape requires bridging large divides between political ecology and land system science (Turner and Robbins 2008). Advances to "pixelize the social" have far outpaced "socializing the pixel," and have focused on local scales and motivations to understand landscape changes. Even more interdisciplinary will be required to understand how illicit and economic capital transform land systems. More of the social sciences- political ecology, institutional economics, economic geography, political science- are required to understand the mechanisms of illicit capital and identify potential proxy data. In kind, the spatial sciences are needed to develop pattern metrics that serve as indicators for the clandestine transactions described by the social sciences (in essence, socializing the pixel). Beyond just people and pixels, power and politics represent the next frontier of interdisciplinary inquiry for human-environment systems. Truly linking clandestine processes to landscape patterns calls for a more political land change science that continues to fulfill its mission of understanding the causes and consequences of land change.

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