Artificialised Land and Land Take: What Policies Will Limit Its Expansion and/or Reduce Its Impacts?

Maylis Desrousseaux, Bertrand Schmitt, Philippe Billet, Béatrice Bechet, Yves Le Bissonnais, Anne Ruas

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The concepts of 'artificialised land' and 'land take' refer to specific land use and land use changes, respectively. Initially introduced by agronomists, who sought to identify the causes of agricultural land loss, the implementation of these concepts required the identification of various land uses and changes between them.[1] This has resulted in a distinction between four main types of use: agricultural uses, forestry uses, areas considered 'natural' and the rest, comprising 'artificialised land'. The

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– Béchet (coord.), Le Bissonnais (coord.), Ruas (coord.), et al. (2017a). *Sols artificialisés et processus d'artificialisation des sols, Déterminants, impacts et leviers d'action*. Rapport d'expertise scientifique collective réalisée à la demande du MTES, du MAA et de l'ADEME, IFSTTAR & INRA (France), 609 p.;

– Béchet, Le Bissonnais, Ruas (coord.), Schmitt B., Savini I., Desrousseaux M., et al. (2017b). Artificialised land and land take processes: drivers, impacts and potential responses. Summary of the collective scientific report, IFSTTAR-INRA (France), 127 p.

[1] Slak and Vidal (1995).

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term 'land take' is therefore a negative construct; it designates areas removed from a natural state (wasteland, natural grassland, wetland, etc.) or from forestry or agricultural uses. This definition covers a wide range of land uses and surface coverings, and with varying impacts from different processes. These include built and unbuilt spaces that have the common characteristic of being strongly shaped by human activity (housing, industrial buildings, roads, office buildings, construction sites, quarries, mines, dumps, etc.). Green spaces associated with these uses (parks and gardens, sports and leisure facilities, etc.) are also considered to be artificialised land.

Despite the lack of a clear, inclusive definition, and the consequent difficulty in precisely determining its boundaries and heterogeneity, the concept of 'land take' has flourished in public debates and political discourse. Because of the major environmental impacts of human development on these areas and their continued expansion, land take is now recognised as one of the main causes of biodiversity loss. It has been one of the government's 10 'new wealth indicators'[2] since 2015 based on the work of the Stiglitz Commission[3] and appears alongside growth indicators, employment, human capital, social inequality, etc. as one of the two indicators of environmental impact on French society (as well as carbon footprint, as measured by greenhouse gas emissions). It was already recognised as an issue in the National Biodiversity Strategy 2011–2020 and was part of the seven indicators proposed in France's 2014 Strategy to measure the 'quality of growth'.[4] Consequently, Prime Minister Edouard Philippe specifically directed his environment minister, Nicolas Hulot, to propose strategies 'to fight against land take and the depletion of soils, one of the main threats to biodiversity'.

The importance of the issue of land take is usually emphasised in the public debate by statements such as 'artificial land generates a loss of land resources for agricultural use and natural areas', which indicates that its role in the degradation of biodiversity and in the loss of agricultural land should be considered together. This dual-faceted impact is ambiguous, however, as the preservation of agricultural land and biodiversity are not necessarily convergent. It is legitimate to seek to limit the environmental impacts of land take, as with all other human activities, and this objective may be met in two ways: through changes in the methods of artificialisation and organisation of these 'artificialised' spaces and by controlling the expansion of these types of use.

Given the importance of land take in the public debate, and before considering the policy levers that can limit its expansion or reduce its negative impacts, it is necessary to better understand the phenomenon and precisely define its nature in order to better understand its extent and impacts. In doing so, one encounters the technical difficulties of its measurement and the false equivalence between the related concepts 'land take', 'waterproofing' and 'urbanisation'.

[2] Service d'information du Gouvernement (2015), 74 p.

[3] Stiglitz et al. (2009), 324 p.

[4] Ducos and Barreau (2014), 12 p.

1 A Difficult-to-Grasp Concept, Artificialised Land Is the Variety of Land Use Supporting All Human Activities Other Than Agriculture and Forestry

Although this definition is based on the exclusion of certain land uses, 'artificialised land' comprises a wide variety of uses (in other words, all human uses other than agriculture and forestry). It therefore covers very different types of land use, with differing economic, social and spatial characteristics. Their delineation and measurement pose the first question.

1.1 Disagreements in Measurement

In attempting to measure land take in France, and in spite of the (relative) simplicity of identifying 'artificialised land' in principle, the object of the measurement, as well as methods, is problematic. This is illustrated by the significant discrepancies between the main statistical sources. For example, according to the Ministry responsible for Agriculture (using the French Teruti-Lucas data based on statistical surveys), 9.3% of French land was classified in 2014 as 'artificial land', whilst the Ministry of the Environment (using the European-wide Corine Land Cover data derived from remote sensing) estimated it to be 5.5% in 2012 (see Tables 1 and 2). Moreover, this national gap is accompanied by a strong inter-regional variability between the measurements; differences between the two techniques range from 2% for Île-de-France, whose artificialised surfaces are strongly agglomerated, to over 50% for regions where the land take is more limited but more dispersed.

The source of these discrepancies is found in the differing specific methods and techniques used to identify land use. Two elements in particular underline the limitations of the current tools. The first relates to the spatial resolution thresholds of remote sensing tools (for example, land use areas of less than 25 ha are not included in the Corine Land Cover measurements). The second relates to interpretation bias in the field or sampling bias inherent in statistical tools used in the Teruti-Lucas measurements. To overcome these limitations, efforts are currently underway to improve these methodological approaches. The basis of this is the availability of finer-resolution remote sensing data, along with the use of geographic information systems (GIS) (data integration, including cadastral data and linear features), which now make it possible to obtain more precise results. Increasing numbers of local authorities are now using these approaches for their planning documentation, and the expansion of these approaches to the entire country will allow more precise monitoring of the overall dynamics of land take.

Currently, the available data on land take in France illustrates the main trends in the phenomenon, but no quantitative measurement exists as a definitive reference for all relevant parties. These sources do clearly show, however, that land take is continuing, and comparative studies at international and European scales show that France lies near the European average, both in the proportion of artificialised

t1.1 **Table 1** Distribution of the area of mainland France by nature of occupancy according to Corine Land Cover 2006 (corrected data) and 2012

t1.2		2006			2012		
t1.3		Mha	% artificialised land	% total surface	Mha	% artificialised land	% total surface
t1.4	Continuous urban fabric	0.044	1.5	0.1	0.044	1.5	0.1
t1.5	Discontinuous urban fabric	2.208	74.8	4.0	2.253	74.3	4.1
t1.6	Industrial zones, commercial and public installations	0.359	12.2	0.7	0.385	12.7	0.7
t1.7	Transport infrastructure	0.103	3.5	0.2	0.109	3.6	0.2
t1.8	Other economic activities	0.098	3.3	0.2	0.098	3.2	0.2
t1.9	Green spaces and recreational areas	0.141	4.8	0.3	0.143	4.7	0.3
t1.10	**Artificialised land**	**2.953**	**100.0**	**5.4**	**3.032**	**100.0**	**5.5**
t1.11	Agricultural land	32.696		59.6	32.619		59.5
t1.12	Forest and natural lands	19.202		35.0	19.192		35.0
t1.13	**Total surface**	**54.851**		**100.0**	**54.843**		**100.0**

t1.14 Sources: SOeS, MTES

t2.1 **Table 2** Distribution of mainland France areas by nature of occupancy according to Teruti-Lucas surveys 2006 and 2014

t2.2		2006			2014		
t2.3		Mha	% artificialised land	% total surface	Mha	% artificialised land	% total surface
t2.4	***Built-on land***	***0.756***	***16.5***	***1.4***	***0.923***	***18.1***	***1.7***
t2.5	***Coated or stabilised surfaces***	***2.159***	***47.3***	***3.9***	***2.456***	***48.1***	***4.5***
t2.6	Non-linear areas	0.719	15.7	1.3	0.841	16.5	1.5
t2.7	Linear areas	1.441	31.5	2.6	1.615	31.6	2.9
t2.8	***Other artificial lands***	***1.653***	***36.2***	***3.0***	***1.725***	***33.8***	***3.1***
t2.9	Grassed land	1.465	32.1	2.7	1.583	31.0	2.9
t2.10	Unvegetated land	0.188	4.1	0.3	0.142	2.8	0.3
t2.11	**Total artificialised land**	**4.568**	**100.0**	**8.3**	**5.104**	**100.0**	**9.3**
t2.12	Agricultural land	28.591		52.1	28.029		51.0
t2.13	Forested land	17.042		31.0	17.033		31.0
t2.14	Other uses	4.718		8.6	4.752		8.7
t2.15	**Total surface**	**54.919**		**100.0**	**54.919**		**100.0**

t2.16 Sources: SSP, MAA

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land and the rate of ongoing land take. However, land take in Europe is less intense than in other regions of the world.

Nevertheless, the uncertainty in the data on land take makes it difficult, indeed risky, to evaluate (especially quantitatively) the causes of land take and its effects on the environment or on agriculture. This issue of the precision of measurement is important given the prominence of the rate of land take in public debates and public policy monitoring, the latter being directly linked to biodiversity protection.

The use of land take measurements for the evaluation of impacts and determination of causes is further complicated by the very heterogeneous composition of 'artificialised land' and the divergence in the way they are classified by the two main tools currently used. Corine Land Cover focusses more on urbanisation, whereas Teruti-Lucas focusses more on the identification of permeable versus non-permeable surfaces (see Tables 1 and 2).

1.2 Is the Sealing of Surfaces Synonymous with Land Take?

All soils in artificialised lands undergo strong disturbances of their biogeochemical and physical characteristics through the extraction of material, inputs of exogenous materials (often mineral), mixing different soil horizons, changes in the nature of their cover, etc. Therefore, soil as a natural environment and ecosystem will be most directly affected by the change of use. Its structure, chemistry, biology, biodiversity (endogenous) and the ecology of its organisms will be modified to varying degrees. These changes, associated with the particular activities that develop on these soils (classified as SUITMA (Soils of Urban Industrial Traffic and Military Areas)), also strongly impact terrestrial (epigee) and aquatic biodiversity, air and water quality, and the human living environment, regardless of the method of land take.

However, not all artificialised lands undergo a literal 'waterproofing' or 'sealing' of their surface. Significant areas of 'artificialised land' are not covered with a hermetic mineral cover and are therefore not 'sealed'. Thus, the Teruti-Lucas data (Table 2) identifies more than 30% of the artificialised land in 2014 as 'artificial grassed land'. These substantial areas (1.6 Mha) mainly correspond to green spaces, recreation and leisure areas and private gardens associated with individual housing. The environmental impacts of areas with these types of vegetative cover differ substantially from those with 'built land' type cover (less than 1 Mha in 2014) and from the sealed or 'macadamized' portion of the 2.5 Mha of 'coated or stabilised soils', whether linear (roads and other transport infrastructure) or non-linear (car parks, building yards, etc.). The presence of vegetated land within a matrix of sealed areas also has the advantage of reducing the environmental impacts of the latter, particularly in terms of animal and plant biodiversity, urban hydrology, landscaping, urban microclimate, etc.

The degree of ground sealing or, more generally, the level of disturbance to the ground is the method favoured by soil scientists and most biologists. Given the

effects that each type of cover or disturbance may have, the way in which they combine to form a landscape or a 'landscape mosaic' then constitutes an important reading grid for environmental and other impacts.

1.3 Urbanisation, a Major Driver of Land Take, Continues Beyond City Borders

As a major characteristic of contemporary societies, urbanisation represents a large component of artificialised land and is clearly a major driver of land take and related land use changes. Across the history of humankind, urbanisation is a recent but inevitable phenomenon. The rate of urbanisation amongst the global population has just passed 50%, whilst in France almost 80% of inhabitants live in an 'urban unit', a rate comparable to that of other industrialised countries. Historically, increases in agricultural productivity and the consequent emergence of agricultural surpluses allowed cities to develop. People who were able to exit agricultural economies established themselves at the junctures of communication routes (usually fluvial) and agricultural areas that were sufficiently productive to create the food surpluses required by the city. With the advent of the Industrial Revolution, the circular and cumulative causation underlying the mechanisms of contemporary urbanisation were set in motion. With economies of scale (within firms) and economies of agglomeration (market and non-market), companies benefit from being closer to each other, thereby encouraging industrial firms to concentrate geographically, either in existing cities or around the required natural resources. This industrial concentration then attracts workers that, because of productivity gains, are surplus to the agricultural sector. This migration to urban centres in turn increases the size of local markets for goods and services and for labour, thus attracting more firms to join the agglomeration. AU4

Nevertheless, the agglomeration of populations and economic activities in a small number of locations creates a trade-off in the price of land. This increase in land prices most heavily impacts people for whom housing forms a large proportion of their budget. Consequently, cities will tend to spread as their population grows, increasing their land use and changing their shape.

Urban sprawl occurs according to two contradictory processes depending on the geographical scale of observation. At the national or continental level, metropolisation attracts a concentration of social and productive assets to the largest cities. At the local level, however, the dominant trend is to spread because the increasing land prices resulting from this concentration. Two major forms of urban sprawl can be distinguished. In the first, the city extends by expanding its own urban boundaries, with new urban development adjacent to pre-existing city developments. The second is discontinuous, with populations or companies moving to villages or small cities close enough to the city to commute for work but far enough to remain separate from the city (Fig. 1).

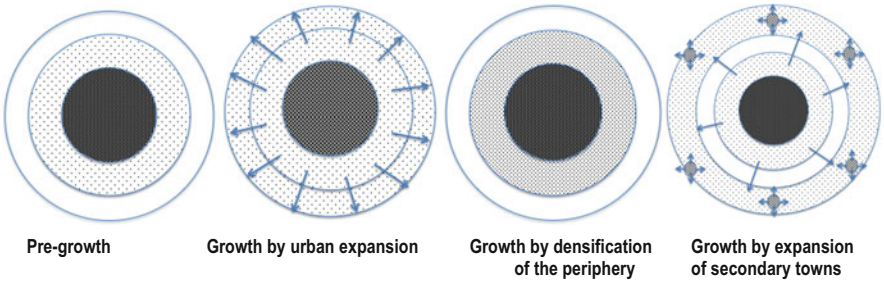

Fig. 1 Different forms of urban sprawl (Grayscale, darkest to lightest, corresponds to population density, from highest to lowest)

The first form of urban sprawl thus enlarges the surface of the city and expands its borders. The land take occurring in these areas clearly represents urbanisation in the strict sense. The second densifies the peripheral areas, which, without becoming urban, do not remain as rural but become 'peri-urban'. In this case, the resulting land take is linked to the process of urbanisation, but it takes place in municipalities external to the city (representing a continuously built-up area).

This process of low-density peri-urbanisation took place in France and throughout Europe at a relatively late date. Since the early 1970s, however, it has radically transformed the demographic balance between urban and (particularly) peri-urban areas and French landscapes. The territory now under urban influence covers a large part of the national territory, with only 7400 of the 36,700 French municipalities being excluded from 'Zoning in urban areas' (ZAU 2010, INSEE). Over 95% of the metropolitan population is now under urban influence. Whilst almost 50 million French people now live in a so-called *pôle urbain* (urban centre), nearly 22 million reside in a peri-urban municipality, most often within the influence of one (or more) of the 241 large urban centres.[5] The difference in population density between the urban areas and the peri-urban crowns to which they extend is significant; large urban centres have a population density of 820 inhabitants/km^2, which decreases to 72/km^2 in the peri-urban areas surrounding these same urban centres, leading to different land take issues.

Initially driven by city workers seeking to reside outside cities but still commute for work, the phenomenon of urban sprawl gradually spread to companies (firstly commercial and then logistical and industrial) that now tend to locate in peri-urban areas. In addition, between cities and within these areas, a dense network of transportation infrastructure (rail and road) has developed to improve the service to and from peri-urban areas as inter-urban links. The resulting land take therefore also affects more distant rural areas (i.e., non-peri-urban areas) and then connects to other types of land take related to the development of tourism and leisure activities,

[5]Brutel and Levy (2011), pp. 1–4.

second homes and industrial and commercial enterprises for which these locations provide certain advantages.

This dual process of urban sprawl by extension of urban surfaces and the development of peri-urban areas is highlighted by the Corine Land Cover data set, which reveals that in France, the 'urban fabric' (continuous or discontinuous) increased by almost 2% between 2006 and 2012 to 2.25 Mha in 2012 (Table 1). Correspondingly, the Corine Land Cover (which underestimates land take in sparsely populated areas) estimates that 25% of artificial lands are created outside the urban fabric and that the growth of these surfaces is faster than those considered to be within the urban fabric (+4.8%).

1.4 An Analytical Framework for the Impacts of Land Take That Accounts for the Heterogeneity of the Process

Land take cannot be reduced simply to the sealing of soils nor to urbanisation in the narrow sense of the word. Neither of these terms take into account all of the dimensions of land take, and evaluating its impact should reflect this complexity. If the components of land take are multiple and complex, the analysis of its causes and consequences will be equally so. To clarify the issues, it is necessary to use an analytical framework to align our understanding of the impacts of this phenomenon in the specific and varied contexts and the manner in which it takes place. The above analysis of the causes and consequences of land take suggests that policies to limit the negative impacts of land take and/or its expansion must consider the following three dimensions:

- The nature of the disturbance and the type of surface cover after its 'artificialisation' (waterproofing, mineralisation, vegetative cover, etc.)—if possible, its position with respect to other types of land take with different surfaces (in other words, the landscape mosaic in which it sits) should be considered. For example, the intertwining of mineralised surfaces and surfaces with vegetative cover tends to reduce the environmental impacts of land take.
- The position in the urban fabric (centres of dense cities, suburbs, zones of extension of the city's borders, peri-urban areas, municipalities outside urban influences)—the agricultural and environmental consequences of land take differ in their nature or intensity depending on whether one is in urban, peri-urban and rural areas, and the policies to combat them will also differ.
- The type of activities that take place (individual or collective housing, industrial activities and their nature, tertiary activities, commercial and logistical activities, transportation infrastructure, etc.) also directly influences the nature and intensity of environmental impacts.

The simultaneous consideration of these three dimensions allows for a more precise understanding of the causes and consequences of land take, a more rigorous appreciation of what is at stake and a more appropriate adaptation of public policy instruments to reduce negative impacts on the environment or on farmland.

2 Efficient but Ill-Equipped Public Policy Instruments and Regulations to Control Land Take

Current national and local government policies are intended to regulate land take and reduce its impacts. However, these policies, which apply to rural areas, as well as cities and their suburbs, have limited and even conflicting effects on land take as some policies encourage land take, whilst others seek to control the process. An initial analysis of these measures suggests that land take may be tackled according to three types of policy: those designed to avoid land take, those aimed at reducing the impacts of land take and (more aspirational given current French law) those aiming to offset the effects of land take on the environment or on a given activity (in particular, agriculture).

2.1 Avoiding Land Take in a Context Where Many Legal Measures Encourage It

This is the major issue in public policy, whereby implementation of the policy is made difficult because of fragmentation of the governance that relates to land take, with no specific authority or institution ultimately responsible. Thus, contradictory public policies with regard to land take are regularly implemented. For example, incentives currently exist for the construction of new homes on undeveloped land (land not yet sealed), which conflicts with the objectives of preserving urban biodiversity and limiting the loss of agricultural land or natural areas.

Some legal provisions clearly have the aim of compelling communities to start new construction projects, which more or less imposes land take on communities. This is the case with the Local Housing Programme (PLH) or with the Urban Solidarity and Renewal (SRU) Law of 13 December 2000 on social housing and incentive-based measures such as those for rental investment and access to home ownership (zero-rate loans, etc.).

Simultaneously, recent and contentious legal changes have tightened the rules against private persons or corporate entities that might contest a construction project, thus strongly reinforcing rules in favour of urbanisation. Recent legal changes have restricted the opportunities for associations to appeal; an environmental protection association can no longer appeal against an administrative decision on land planning in direct relation to its status and its impact on the environment if that decision was taken before the creation of the association. Whereas before the changes being a neighbour was a sufficient ground for an appeal, now the applicant must show how its goods and uses are directly affected. In addition, appeals against a project on the ground of procedural errors or mistakes in the urban planning documents must be filed within six months from the moment they have an effect, except for severe violations of rules. Judges have increasing powers in terms of regularisation of these documents or of administrative decisions.

Minor modifications could regulate land take, or at least see land used more efficiently, without necessarily calling entire construction projects into question.[6] For example, changes may include making grants and subsidies subject to the efficient use of land, which implies prioritising land reclamation over land take, or requiring the provision of a study making the case for the project in the municipal or inter-municipal context. Priority would be given to urban renewal operations under the same conditions of demonstration of land availability. To regulate certain specific cases, such as limiting second homes (known as 'cold beds' because of their low occupation rate), France could draw on the experience of other countries. For example, to regulate this phenomenon, which particularly affects mountain tourist areas, the Swiss federal law on second homes of 20 March 2015 prohibits their construction in municipalities that already have or would have more than 20% should authorisation to build be granted.

Fiscally, modifying the new planning tax (replacing the ex-local equipment tax since 2010) would create a useful tool that could, for example, apply variable rates depending on soil quality or land availability. Rates might also vary depending on whether the project involves previously vacant land in order to increase the cost of projects on greenfield sites.

2.2 *Avoiding the Artificialisation of Specific Types of Areas*

The law identifies particular areas to which more restrictive anti-land take measures should apply. Some examples include the Mountain Laws and Coastal Laws, which specifically aim to protect important natural and cultural areas, agricultural land, forestry, outstanding areas and the coastal line, respectively. However, these two laws are not without significant anomalies since sporting facilities, for example, are still permitted in the agricultural areas of the mountains, as are limited extensions of old alpine chalets or summer buildings that relate to a seasonal professional activity. Coastal land protection mechanisms have often been put in place belatedly (notably because of political and institutional failures and local 'resistances') given the rapid and largely spontaneous dynamics of artificialisation. In addition, tools often serve the purpose of promoting economic development rather than protecting the environment, showing the schizophrenia of integrated protection instruments. A 2014 review of the coastal law, which was first adopted in 1986 in order to preserve this area and to limit its urbanisation, concluded that it was applied with only mixed success.[7] It did not call into question the legitimacy of the specific coastal policy; on the contrary, this assessment pointed to shortcomings in its implementation and called for a revision of certain provisions.

[6] Billet (2017), pp. 255–271.

[7] Herviaux and Bizet (2014), 114 p.

As a central theme of the fight against land take, the preservation of agricultural land involves the implementation of many specific tools. Their main objective is to preserve the availability of land. The classification of a parcel in Area A (Agricultural) by local planning documents has the effect of limiting its availability for construction. This protection of land for agricultural purposes also requires the input of agricultural and related bodies when the municipality or inter-municipal body allocates zones. The Chamber of Agriculture is consulted during the development of planning documents, and the Prefect of the Department may designate the relevant public department that must be consulted. If the planning document and any amendments (modification/revision/update) leads to a reduction of the agricultural and forest lands, the Chamber of Agriculture and the Regional Centre for Forest Ownership must be consulted and, where relevant, the National Institute of Origin and Quality (INAO).

However, this input, along with other consultation, offers only a weak defence against changes in land use. The protection of agricultural land must therefore go through *ad hoc* mechanisms. This is the case for protected agricultural zones (PAZs), which come under the Prefect's jurisdiction; whenever a change in land use or tenure that permanently affects the agronomic, biological or economic potential of an area is planned, the Chamber of Agriculture and the Departmental Committee for Agricultural Orientation are consulted. Should one of these bodies provide an unfavourable opinion of the proposed change, the Prefect must provide reasoned arguments if authorising this change (C. rural, art L. 112-2). This regime makes it possible to go beyond the short-term economic horizon and to counter local pressure on elected officials, but it is very rarely applied because its implementation is not mandatory.

Peri-urban agricultural areas have benefited from special preservation measures since 2005 (Rural Areas Development Act). Departments may define protective perimeters around peri-urban, agricultural and natural spaces (PEAN). The advantages of this measure are that the land included in a defined perimeter cannot be included in a zone that is or could be urbanised, nor identified as a buildable zone on municipal maps, and any modification of the perimeter can only occur by formal decree. However, such protection remains fragile because it depends on the goodwill of the Departmental Government, and it has a somewhat vague coverage as the term 'peri-urban' does not clearly identify these spaces. Finally, local food and agricultural policies emphasise the important role of planning tools. The protection of peri-urban agriculture through municipal planning instruments would be more effective than PLUs since they would express the local desire to protect agricultural land through joint investment in an agri-urban development project.

Against this background, fiscal tools may be useful, but procedures and tax rates are currently at inappropriate levels, making them ineffective. This is the case with capital gains tax on real estate, which is based on the sale of bare agricultural land made constructible.

2.3 Densification of Already Artificialised Areas Requires a Strong Will but Leads to Positive Outcomes

Land take often results from urban sprawl (continuous or discontinuous). The approach to densification outlined by the SRU Law and its headline 'rebuild the city over the city', updated by the ALUR Act (2014), frees up densification and provides a stronger legal framework for densification, in concert with fiscal incentives to densify. However, densification has impacts on biodiversity and human well-being. The threshold effects of urban density have been highlighted by studies focussing on species and assemblages and should be given greater consideration in proposals that focus on limiting urban sprawl. The policy of limiting urban sprawl, despite its advantages (limiting the loss of agricultural and forestry land, reducing the carbon impact of cities), should be accompanied by specific measures to limit or compensate the adverse environmental effects of urban densification in the heart of cities.

The measurement of urban density had long been carried out using the land use coefficient (COS), a simple and easily calculated measure, but it over-simplifies the issue of density by employing an exclusively mathematical approach. Indeed, apart from some exceptions, e.g., allowing the definition of a maximum permissible density on a given land parcel by applying a ratio related to the land surface, the COS has limits in its ability to estimate an optimal level of density. It requires looking elsewhere for the required building capacity for a project, especially if the COS is low, as it then restricts the densification of the land concerned. The ALUR Act has removed the COS, making densification of land possible. At the same time, that law abolished the regime of minimum surface area for building land in order to strengthen the intramural supply of land and avoid a peripheral extension of the city. By deleting the COS, the ALUR law also modified the methods for calculating the minimum density threshold used for calculating the sub-density charge.

The payment for sub-density is a tool in the fight against urban sprawl. Municipalities may establish a minimum density threshold below which an under-density payment is due. Below this threshold, developers must pay a charge based on the value of the land and the missing surface not urbanised to reach the threshold. Whilst this mechanism creates an incentive to use space more economically, it remains optional as the choice to implement it falls to individual municipalities or inter-municipalities. Making its implementation compulsory for all municipalities and inter-municipalities would provide an additional tool to raise awareness of the need to preserve land and to make developers more responsible.

2.4 How to Reduce the Impacts of Land Take

When land take cannot be avoided, for example, to satisfy legitimate housing needs or economic development, or because no legal mechanisms have called the project

into question, levers exist to reduce the impacts of soil artificialisation on the land and on the environment more generally.

2.4.1 Knowledge of Soils and the Environment Prior to Artificialisation, a Public Policy Issue

The scope of the environmental assessment mechanisms does not cover a significant number of operations that ultimately result in land take, such as electricity generation works from solar energy below 250 Kwc or most building or development permits under the surface thresholds beyond which an impact study is required. In addition, knowledge of the soil is often neglected by these assessments, which is detrimental in the long term given the non-renewable nature of this resource on a human scale. There is no doubt that greater consideration of soil quality would considerably reduce the impact of artificialisation on the environment. However, there is a significant deficit of baseline knowledge of the environment and, in particular, soils, which prevents a true measurement of the impact of artificialisation. The requirement to measure and maintain the condition could be imposed by the law and be modelled on a mechanism similar to that of preventive archaeology, which is already in force. This would be a form of preventive soil science. Meanwhile, rehabilitation measures provided for in some impact studies would provide for the 'de-artificialisation' and renaturation of spaces.

2.4.2 Land Use and Soil Quality; Should a Tool Be Created?

Soil quality is rarely used as a factor cancelling the decision to classify land as buildable, unless there was an obvious error of assessment. This situation highlights the fact that the classification is more often the result of a desired assignment than the quality of the soil. To reverse the trend in the long term would probably involve following the Uqualisol-ZU project (soil use and soil quality in urban and peri-urban areas—application to the Provence Mining Basin) and its recommendations, formulated under the 'Gessol 3' programme. It would require the creation of soil quality indices and their integration into urban planning documents. These indices would allow correlation with the possible uses of the soil in order to allocate it as accurately as possible to different land uses according to their qualities. Thus, high-quality soils would not be 'wasted' by artificialisation. Moreover, it could create greater responsibility on the part of the municipalities and inter-municipalities, which would need to justify a land zoning decision that differs from that suggested by the soil index.

2.4.3 Land Recycling

One major challenge to reducing the impacts of artificialisation lies in preventing the conversion of agricultural or natural parcels to a non-reversible artificial state,

implying the mobilisation of already artificialised areas to satisfy the construction needs. The reconversion of former industrial or commercial land into dwellings or public buildings is of concern to the public authorities who must attempt to regulate the rehabilitation of polluted sites and contaminated soils. In this case, soil conservation can conflict with the preservation of human health. Despite important progress in terms of liability and remediation thresholds (polluter-pays principle, careless landowner,[8] etc.), French law is weak in this area and the number of disputes attests to the uncertain position that public authorities and project developers find themselves. There is an urgent need for improved tools, project financing and control procedures. One strategy may include the establishment of an urban soil quality baseline accompanied by a strong, punitive legal framework.

2.4.4 Limiting the Sealing of Artificial Spaces

Ground sealing makes the reversal of land take very difficult or even impossible. In terms of biodiversity, but also water management, tools exist to limit the use of waterproofing without necessarily threatening the intended use.

Created by the ALUR Act, the biotope coefficient applies at the municipal or inter-municipal level; the PLU can set rules imposing 'a minimum allocation of permeable or eco-sustainable surfaces, possibly weighted according to their characteristics, in order to contribute to the maintenance of biodiversity and nature in the city'. Based on a ratio of area favourable to the nature of a constructed parcel, this coefficient makes it possible to determine the portion of the area of a site that is vegetated or performs other ecosystem functions. This tool is useful for mitigating the adverse effects of urban heat islands. AU7

Land rehabilitation appears to be on the agenda, with progress illustrated, for example, by the Biodiversity Law of August 2016, which requires new car parks to be permeable.

2.5 Can We Compensate for Land Take?

Currently in France, there are no specific mechanisms to offset artificialised land and/or its most important impacts. However, agricultural collective compensation, forestry compensation and the classic French mechanism of Environmental Impact Assessments highlighting the need for compensation may all warrant further investigation.

[8]The concept of 'careless land-owner' is a jurisprudential creation from the law on waste management. If the land-owner has showed a careless behaviour, by not watching his/her land, or by renting it without paying attention on the activity, he/she can be found responsible for its pollution and the wastes. It has since be inscribed into the law.

Compensation firstly requires that an impact be identified, which as outlined above can constitute a major obstacle, especially regarding the intrinsic value of soil. For example, whilst the impact of road infrastructure is usually assessed with respect to water, air, landscape and biodiversity, impacts related to the underlying soil are usually ignored. The same is true for the environmental assessment of planning documents. If the legislation were to change, the compensation measure could consist, for example, of the rehabilitation of artificial soil by covering it with its natural features or the preservation of environments that compensate for the ecosystem services affected by the land take.

On the other hand, compensation for forestry and agriculture land take are geared towards offsetting the impacts on an economic activity. The Forest Code, for example, makes forest clearing operations subject to the condition that other afforestation or reforestation works be carried out on an area of similar size to the cleared area, including, where appropriate, a multiplying factor between 1 and 5, determined according to the economic, ecological and social values of the timber and forests subject to clearing or other silvicultural improvement works of an equivalent value. Finance Law for 2014 has created a Forest and Timber Strategic Fund, which allows the developer to fulfil his obligation by paying an amount of equivalent value. It is dedicated to the Forest State Programme to fund, notably, reforestation operations.

Since the enactment of the Law for the Future for Agriculture, Food and Forestry (2014), a study must precede works or any public or private developments that could have significant negative consequences on the agricultural economy. This mechanism is interesting from the point of view of artificialisation, but its scope is limited because of restrictive criteria.

Germany is regularly cited as an example of a country having implemented a compensation mechanism for land take. In fact, since the end of the 1990s, urbanisation has been offset using an 'ecopoint' market (tradeable environmental credits) run by agencies at the state (Länder) level. The principle is quite simple: compensation agencies buy and manage areas eligible for compensation, which produces 'ecopoints'. These ecopoints are sold and used to allow ecologically impacting projects in another area. It is a compensation bank, similar to American mitigation banking and compensation units created by the French Law on Biodiversity of 2016. These mechanisms can be managed by trustees.

A development charge is also under consideration. Examples include the Czech Republic and Slovakia, which have both created a classification of agricultural land according to their fertility. When a project involves the conversion of high-quality land, the developer must apply for a special permit issued either by the Region or the Ministry of the Environment and pay a sum corresponding to the price per square metre multiplied by the artificialised surface. However, this mechanism is considered very lenient given the fees, especially in zones of strong land pressure. A current French example is the transfer of building rights. This economic tool could influence land and real estate markets by allowing a developer to increase the density on a parcel by buying unused rights on another parcel of the same area.

3 Conclusion

French policies are far from solutioning the issue of land take according to the recent statistics. Avoiding, reducing and offsetting land take, particularly in its most impactful and least reversible forms such as the sealing of surfaces, are three objectives whose success requires the joint implementation of various economic, legal and fiscal tools, which have not necessarily been designed for these purposes. The confusion revealed by several authors surrounding the concept of land take, referenced in the published assessment, has hindered the creation of an overall strategy, which in turn has greatly reduced the effectiveness of existing sectoral policies. This confusion causes also difficulties of measurement in terms of surfaces and impacts. The scientific outcomes of the assessment call for a broader reflexion on the concrete scope of the concept of artificialisation and its uses to guide efficient public policies.

Despite the political impetus for ecological transition to more controlled growth (2013), there has been little research on the financial and fiscal instruments that would encourage densification. This is due to the lack of specialists in these areas rather than the technical nature of the exercise. This issue has been addressed by the French Committee for Ecological Taxation (now called the Committee for the Green Economy), but its inputs remain unapplied. The law comes as a solution, and this article calls for a global legal principle included in the urban Code, which would guide land planning.

No doubt that the recognition of the soil as an ecosystem and the recognition of its ecosystem services by the French Environmental Code would constitute a useful first step towards the awareness of its fragility and value. Thus, environmental impact assessment could take into account the impacts of land take on soils on three dimensions.

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