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# Artificialized land and land take

## Drivers, impacts and potential responses

Maylis Desrousseaux, Béatrice Béchet,
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This book summarizes the collective scientific assessment report jointly requested by the Ministry in charge of the Environment, ADEME, and the Ministry of Agriculture and Food. The contents of the full report and the summary document are the sole responsibility of the authors. The overall report, forming the source of this version, was created in 2019 by the experts without the condition of preliminary approval by the sponsors, IFSTTAR (now université Gustave Eiffel) or INRA (now INRAE). The synthesis was validated by the authors of the report.

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**Contacts:**
Béatrice Béchet: beatrice.bechet@univ-eiffel.fr
Anne Ruas: anne.ruas@univ-eiffel.fr

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# Foreword

**As a major reservoir of biodiversity,** soils are essential for many ecosystem services such as food production, climate regulation, flood mitigation, water quality and air quality. Faced with growing and conflicting demands for housing, commerce, infrastructure, food, raw materials, energy and natural spaces, this limited and non-renewable resource is, at human time scales, subject to strong competition from use and pressures that may degrade quality or limit availability. In this context, 'land take' is often considered, even denounced, as one of the main drivers of soil degradation and loss of agricultural land but also of natural and forest areas.

Therefore, the public authorities attempting to regulate this phenomenon asked IFSTTAR and INRA to produce a Collective Scientific report (ESCo) which summarises the available scientific knowledge of the determinants and consequences of artificialized land and the policy tools that could limit its extension and/or environmental impacts. Supported by the Ministry in charge of the Environment (General Commissariat for Sustainable Development, CGDD, Ministry of Ecological and Inclusive Transition, MTES), ADEME (French Agency for the Environment and Energy Management) and the Ministry of Agriculture and Food (Directorate General of Economic and Environmental Performance of Enterprises, DGPE), this request has four components.

The first component is to try to evaluate the extent of land take in the French territory, relying on the scientific literature and the reports and statistical studies that underlie it, and to clarify the position of France in relation to other OECD (Organisation for Economic Co-operation and Development) countries.

Beyond these measurements, the question of the determinants of land take and of their possible hierarchy is central to understanding the evolution of this land-use change and to identify the land take trends taking shape.

In view of these challenges, it is also necessary to identify the impacts of the phenomenon, both on the biotic and abiotic environment and on the living conditions of populations and economic and social dynamics, with a specific focus on agricultural impacts.

Lastly, policy tools to control land take and to limit the negative impacts require particular examination, as they may be numerous and may converge from or diverge toward each other or other public policy instruments.

To answer these questions, IFSTTAR and INRA applied the classic principles of an ESCo scheme (DEPE, 2018), which is based on international scientific references relating to the various aspects of the issues. As a result, certain phenomena, and in particular recent ones, cannot be precisely assessed, either because of the lack of published work, or because the available studies have been conducted in contexts too far removed from the conditions observed in France. This ESCo also faced an unusual difficulty due to the

polysemy of the term 'soil artificialization'. Soil artificialization ('Land take' in English) as it is understood in France (and in Europe) is essentially a statistical concept used in particular in the CORINE Land Cover database (CLC), but inconsistency between the different scientific disciplines used for this review revealed that the concepts of urbanization or soil sealing were often preferred. However, these three concepts, although they partly overlap, are not exactly synonymous, which, while contributing to the richness of the work, has increased its complexity. Therefore, the literature review component of this expert summary required many adjustments and several combinations of key words so that each discipline, approaching the phenomenon through different concepts, could contribute on a firm conceptual footing. In addition, the experts have, according to their disciplines, made important additions.

Fifty-five French-speaking experts from various institutions (IFSTTAR, INRA, CNRS, Université de Saint-Etienne, Paris-1, Brest, Montréal, etc.) contributed to this study. Some coordinated components of the review and participated in the integration of different perspectives and disciplines, while others contributed more specifically to the chapter(s) relating to their particular area of expertise. Given the multidisciplinary nature of the issues surrounding land take, the expertise of the experts is varied: they come from economics, geography, ecology, pedology, hydrology, agronomy, law, etc. (see list at the end of this publication).

The results of this study are supported by a bibliography of more than 2,500 references, assembled by two scientific and technical information professionals (INRA and IFSTTAR). This is composed mainly of scientific articles to which some statistical data, books and technical reports have been added. The experts extracted and assembled the relevant elements to clarify the questions.

The ESCo provides neither advice nor recommendation, and is not intended to provide operational responses to questions posed by managers. It carries out a summary of the state of knowledge – as complete as possible – of the determinants and impacts related to land take in France and attempts to identify policy tools through a multidisciplinary approach combining life sciences and economic sciences. It highlights the specific problems associated with this phenomenon. The research organisations, IFSTTAR and INRA, are committed to the terms and conditions under which the expert report was conducted: quality of the documentary work, up-to-date bibliographical sources, transparency of the discussions between the experts, management of the working group and drafting of the synthesis and communication documents in a form that reconciles scientific rigour and readability by a wider public.

# ‘Land Take’, an ambiguous scientific concept

## The statistical measurement of this concept remains uncertain ...

**The concepts of ‘artificialized land’** refer to specific land use and land use changes, respectively. They were initially introduced by agronomists who sought to understand the changes in the French landscape by identifying the various land uses and their changes (Slak and Vidal, 1995a). The approach was intended to support the theory that changes in agriculture ‘have shaped the rural landscape’ and to investigate the causes of loss of agricultural land (Slak and Vidal, 1995b). In statistical terms, this approach has led to the distinction of four major types of land use: agricultural, forestry, spaces considered ‘natural’, and the balance, known as ‘artificialized land’. The term ‘land take’ was thus constructed to designate the conversion of surfaces from a natural state (wasteland, natural grassland, wetland, etc.), or from forestry or agricultural uses. These definitions are therefore a negative construct, and cover a wide range of uses and cover types, with potentially varied determinants and impacts. These include built and unbuilt spaces that have the common characteristic of being strongly shaped by human activity (housing, industrial buildings, 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 artificialized land.

Despite the (relative) simplicity of identifying ‘artificialized land’ in principle (everything that is not agricultural, forestry or ‘natural’), there are significant discrepancies between the estimates from the main statistical sources. According to the Ministry of Agriculture (Teruti-Lucas method), 9.3% of French soils were classified in 2014 as ‘artificial land’, while the European source, favoured by the Ministry of the Environment (CORINE Land Cover estimate), estimates this share at 5.3% in 2012. As will be discussed, these differences can be explained relatively easily by the characteristics of the methods and techniques used to identify land use. Nevertheless, the magnitude of the discrepancies, combined with classifications within non-overlapping categories, makes land take data difficult to interpret when analysing the causes of and prioritizing responses to land take.

## ... but is increasingly used in the public debate

**Despite its statistical uncertainty, the concept of ‘land take’** has flourished in public debate and political discourse. Due to the degree of disturbance that human activities

cause to these areas and their environment and because of their ongoing extension, most often at the expense of agricultural lands, land take is seen today as one of the main causes of biodiversity loss. Since 2015, it has been one of the ten 'new wealth indicators' established by the Government Information Service (SIG), following the work of the Stiglitz Commission (2009): it is included alongside growth indicators, employment, human capital, social inequality, etc., as one of the two indicators of environmental impact of French society (as well as the 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 2014 by France-Strategy to measure the 'quality of growth' (Ducos and Barreau, 2014). It is natural that this concern was therefore expressed in the plan of action issued in 2017 by the Prime Minister to his then Minister for Ecological and Solidarity Transition. In it, Nicolas Hulot was asked to make 'proposals before mid-2018 to combat soil artificialization and soil depletion, which form one of the main threats to biodiversity'. In keeping with this approach, the Biodiversity Plan published in July 2018 includes the objective of achieving a 'zero net artificialization' rate for land by 2050, and the Government is currently working on methods for its implementation[1].

The importance of the issue of land take is usually justified in the public debate by statements such as 'artificial land generates a loss of land resources for agricultural use and natural areas', which infer that its role in the degradation of biodiversity and in the loss of agricultural land should be considered together. This dual-faceted objective 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 human activities, but this objective does not necessarily and exclusively involve controlling the extension of these types of use.

Nevertheless, its prominence in the public debate and the importance that underlies it, combined with the difficulties of defining land take, obliges us to attempt to clarify the scope of this concept and to examine the issues it encompasses. Indeed, artificialization implicitly or explicitly refers to two other concepts: waterproofing and urbanization. Neither of these two concepts, although closer to the concepts used by scientists, covers all the components that the overarching statistical definition seeks to integrate.

## Is the sealing of surfaces synonymous with land take?

**As all soils in artificialized lands have undergone strong disturbances** of their biophysical characteristics by the extraction or addition of material (often mineral), mixing of different soil horizons, changes in the nature of their cover, etc., it is fundamentally the soil, as a natural environment, that will be affected by the change of use. Its structure, chemistry and biology are modified to varying degrees. These modifications, associated with the activities that develop on these soils (which soil scientists classify as

1. Plan biodiversité (Biodiversity plan), Axe (Axis) 1.3, July 2018.

SUITMA - *Soils of Urban, Industrial, Traffic and Military Areas*), may impact all aspects of the environment, including biodiversity (terrestrial and aquatic), air, water and the human environment.

However not all artificialized lands undergo a literal 'waterproofing' or 'sealing' of their surface. Significant areas of 'artificialized land' are not covered with a hermetic mineral cover, and are therefore not 'sealed'. Thus, according to the Teruti-Lucas data, and despite the limitations of this data that will be examined in detail later, more than 30% of artificial soils in 2014 were 'artificial grassy soils'. These substantial areas (1.6 Mha) mainly correspond to green spaces, recreation and leisure areas and private gardens associated with individual housing. We can assume that the environmental impacts of areas with these vegetative covers differ substantially from those with 'built land' type covers (less than 1 Mha in 2014) and from the sealed or 'macadamized' portion of the 2.5 Mha of 'coated or stabilized soils' whether they are linear (roads and other transport infrastructure) or non-linear (car parks, building yards, etc.).

This key to the degree of soil sealing or, more generally, the level of disturbance to the soil, is the one 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 key to understanding environmental and other impacts.

## Urbanization, a major driver of land take, continues beyond city borders

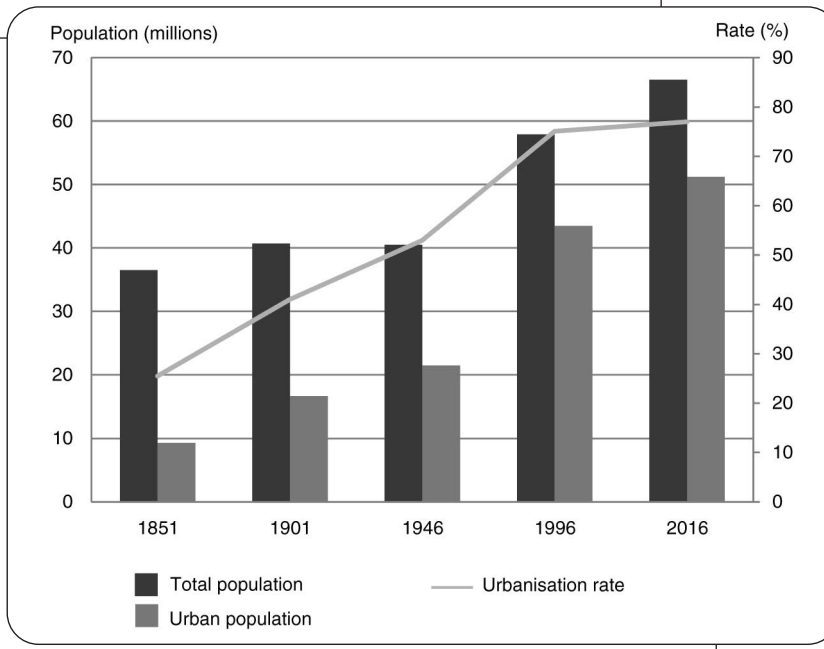
**As a major characteristic of contemporary societies, urbanization** represents a large component of artificialized land, and is clearly a major driver of land take and related land use changes. Nevertheless, even the CORINE Land Cover inventory, which we will see later fails to include some artificial surfaces in low density areas (i.e., in rural areas), highlights the importance of land take beyond the urban fabric; indeed, it identifies that as of 2012, 75% of artificialized land is located within continuous or discontinuous 'urban fabric' (2.3 M² ha), the rest being industrial or commercial areas, road networks, railways, material extraction sites, landfills, construction sites, sports and leisure facilities, etc., which are probably more dispersed through space. Moreover, contemporary urban dynamics, which include urban concentration, urban sprawl and peri-urban development have led to a rethinking of the links between urbanization and land take.

### Urbanization, an unavoidable social phenomenon

Across the history of humankind, urbanization is a recent but inevitable phenomenon. The rate of urbanization among the global population has just passed 50%, while in France almost 80% of the population now lives in a city or 'urban unit' (Fig. 1), a level comparable to that of other industrialized countries. For some European countries, such as Belgium and

Denmark, the rate is close to 90 per cent. No developed country today has escaped urbanization, regardless of its political or economic system, and all emerging and developing countries are now seeing their urban population and their rate of urbanization rapidly increasing. The link between urbanization and development, usually measured by the long-term growth of real gross domestic product (GDP) per capita, is largely accepted. 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 conjunction 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 urbanization were set in motion. Economies of scale (within firms), and economies of agglomeration (market and non-market) where companies benefit from by being closer to each other, encourage industrial firms to concentrate geographically, either in existing cities or around the required natural resources. This industrial concentration then attracts workers that, due to 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.

**Figure 1. Population, urban population and urbanization rates, from 1851 to 2016.**




Source: INSEE.

Nevertheless, the agglomeration of populations and economic activities in a small number of locations creates a trade-off, namely 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, thus increasing their land consumption and changing their shape.

## Europe within the global urbanisation process

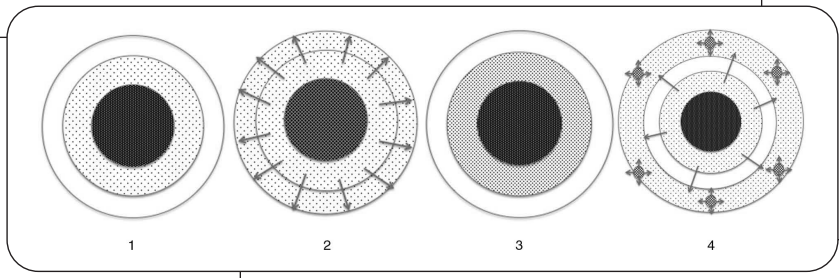
Seen from a global perspective, Europe is a region of small towns, separated by an average of fifteen kilometres. Almost half of the population lives in urban areas of less than 500,000 inhabitants, which clearly differentiates Europe from other continents. As a corollary, the share of the population living in large cities with more than 5 million inhabitants is quite small (less than 5% against 10 to 15% in other regions of the world with comparable urbanization rates). Although Paris belongs to the category of megacities in size, neither France nor Europe is required to manage massive concentrations of people such as those that have developed or are developing in the North-eastern US, Japan, or in the Chinese deltas.

Europe is also distinguished by its average urban densities: compared to other continents, they are in an intermediate position between the extreme dilution of North American cities and dense Asian cities. Broadly, the average urban densities are approximately 2,000 inhabitants per $km^2$ for North American cities, 10,000 to 40,000 inhabitants/$km^2$ for Asian cities, and 4,000 inhabitants/$km^2$ for European cities.

## Urban sprawl, a corollary of metropolization

Urban sprawl occurs according to two contradictory processes depending on the geographical scale of observation. At the national or continental level, metropolization attracts a concentration of social and productive assets to the largest cities. At the local level, however, the dominant trend is to spread, due to the increasing land prices that result 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 close enough to the city to commute for work, but far enough to remain separate from the city (Fig. 2). It is this dual phenomenon of urban sprawl that, in France, led INSEE to develop its Zoning into Urban Areas (ZAU) in addition to its distinction between urban units and rural municipalities (Brutel and Levy, 2011). On the basis of home-to-work mobility and its orientation, it is possible to distinguish between different municipalities that are influenced to a greater or lesser extent by the urban centres (Fig. 3). In the second instance, the continuation of the metropolization trend may also lead to an extension of urban sprawl around secondary peripheral centres that were formerly 'autonomous' (Fig. 2).

**Figure 2. Illustration of the phenomenon of 'Leapfrog', literally 'to exceed' in French, which schematizes the forms of urban sprawl.**




Grey scales, from darkest to lightest, correspond to the density of the population, from the highest to the lowest. 1: Pre-growth; 2: Growth by urban extension; 3: Growth by densification of the periphery; 4: Growth by expansion of secondary towns.


The first form of urban sprawl thus increases the surface area of the city and extends its borders: the artificialization of the land that occurs there is clearly part of urbanisation. The second densifies peripheral areas which, without becoming urban, do not remain rural but become peri-urban. In this case, the resulting artificialization of the land is closely linked to the urbanisation process but takes place in municipalities outside the city (regarded as a continuous built environment).

This process of urban sprawl by peri-urbanisation took place in France and Europe at a relatively late date (the 1960s). It appears to be slowing down, the peak of the movement having occurred before the 2000s. Over a period of some thirty years, between the early 1970s and the end of the 20th century, it transformed the demographic balance between urban and peri-urban areas, as well as the French landscape, particularly the peri-urban landscapes. The territory now under urban influence covers a large part of the national territory (only 7,400 of the 36,700 French towns are excluded) and contains 95% of the metropolitan population (Fig. 3). While nearly 50 million French people live today in a centre, almost 22 million live in a peri-urban municipality, most often under the influence of one (or more) of the 241 large urban centres. The difference in population density between the centres and the crowns to which they extend, is significant: of 820 inhabitants/km² in the large urban centres, the population density drops to 72 inhabitants/km² in the suburbs around these same centres, probably leading to different issues regarding the land take that occurs there.

Initially driven by populations seeking residence outside the cities while continuing to work in them, the urban sprawl gradually spread to companies (first commercial, then logistical, then industrial) that today tend to reposition their new establishments in peri-urban areas.

In addition, a dense network of transport infrastructure (rail and road) has developed between cities and within their areas, aimed both at improving access to peri-urban areas and improving interurban links. The resulting land take thus also affects more distant rural areas (i.e. not peri-urban), and then becomes linked with other types of land take such as tourist and leisure activities, second homes, and industrial and commercial enterprises that are subsequently attracted to these areas.

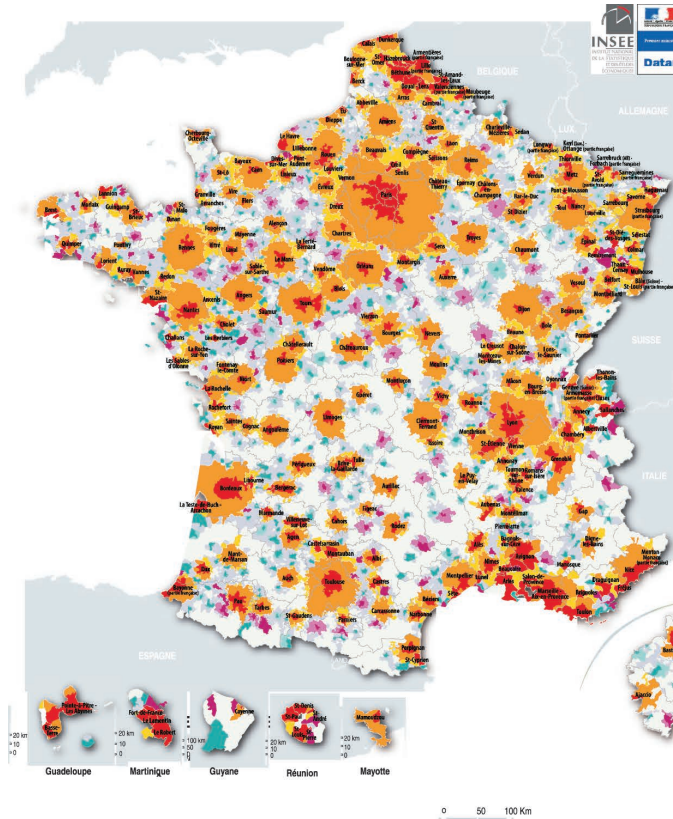
Thus, land take cannot be reduced either to the waterproofing of part of the soil or to urbanisation in the strict sense of the term. Neither of these two approximations makes it possible to take into account all the dimensions covered by the statistical definition of this concept. Its components are multiple and complex; consequently, so will be the analysis of its causes and consequences. To try to understand this clearly, it appears necessary to have an analytical framework that can serve as a basis for interpreting scientific results, or for repositioning them in the specific French context(s). From the above analysis, it emerges that the causes and consequences of land take, and the measures that could limit its negative impacts and/or its extension, must be understood according to the following three major dimensions:

- the nature of the disturbances and the ground cover after its 'artificialization' (waterproofing, mineralization, plant cover, etc.) combined with the way in which a given surface fits in with local artificial surfaces of different cover, i.e. the landscape mosaic of which it fits;
- its positioning in the urban fabric (centres of dense cities, suburbs, zones extending the city's borders, peri-urban municipalities, municipalities beyond urban influences);
- the type of activities that take place at the location (individual or collective housing, industrial activities and their nature, tertiary activities, commercial and logistical activities, transport infrastructure, etc.).

It is from the simultaneous consideration of these three dimensions that the following scientific results must be understood. Furthermore, in order to evaluate the impacts of the change of land use towards artificialization, it is necessary to take into account the characteristics of the soil before its artificialization.

In order to be more closely aligned with the framework of the current debate on land take, this synthesis has been structured in a way that is strongly oriented towards the issues at stake. After a critical examination of the methods of measurement of land take and the results obtained in the French context (Chapter 1), we will begin by focusing on its environmental impacts, while trying to limit ourselves to the most direct effects on the environment. Since artificialized land supports all economic and social (non-agricultural and non-forest) activities, it is necessary to avoid attributing to the artificialization of soils *all* the impacts of *all* human activities (non-agricultural and non-forest) of which these soils are simply a medium. An initial focus will be on the very direct effects of artificialization on the soils themselves, both in terms of their physicochemical properties and their biology (Chapter 2). Attention will then extend to the impacts of artificialization on their environment, successively addressing the direct effects on terrestrial biodiversity, landscape fragmentation and urban hydrology, and then some of the indirect effects

**Figure 3. Urban zones according to INSEE, 2010.**



on the urban climate and atmospheric pollution (Chapter 3). The consideration of these few indirect effects, which is included in the ESCo's terms of reference, is included as a way to explore some of the negative effects of urbanization that households may seek to avoid by 'peri-urbanizing', thus accentuating land-use changes in peri-urban areas. Particular attention will be given to the direct and specific effects of land take on the agricultural sector and activity, especially in urban fringes and peri-urban areas: loss of agricultural land, reduction of productive capacity, land pressure and conditions for agricultural activity (Chapter 4). The economic and social determinants and impacts of land take will be examined in a second step, and will be organized around household residential location strategies and the resulting demand for housing construction (Chapter 5), followed by strategies for locating economic activities with two specific illustrations: one relating to the construction of warehouses and logistics platforms; the other to transport infrastructure (Chapter 6). Finally, the responses that public policies can make to land take are discussed (Chapter 7).

# 1. Methods of measuring the extent of land take in France

**Given the differences from one French source to another** regarding the extent of artificial surfaces and their recent changes, it is necessary to review both the approaches and methods that are used, and the way in which they are employed as public statistics, in order to understand their uncertainties and limitations. It is on this basis that we can understand the discrepancies found between sources at the French level and be able to analyse the amount and nature of artificialized soils and trends in the progression of land take in France, while placing these trends in a European context. That said, and despite differences in the assessment of the rate of land take, all sources point to the conclusion that there is a trend towards increased land take, both in France and in Europe.

## Objectives and methods for measuring land use change

**None of the methods used to identify** and measure artificialized land and land take are directly aimed at this single objective. All of them are, by their very nature, intended to cover the whole of a territory and to examine the different types of land use that comprise it, and the changes in land use. It is therefore by adapting the categorisation of land uses that their artificialization can be identified, which will appear as a typology of land use categories, itself made up of possible sub-categories. These methods for analysing land use, with their ability to identify artificial soils, are the focus of this study, after having specified the subjects that more particularly concern land take.

### Objectives of the measure

The measured 'objects' are associated with several spatial scales that focus on several types of elements ranging from the building to the parcel, the island, the neighbourhood, the agglomeration or even the urban footprint. The measurement of land take refers to three things: surfaces, the urban footprint and land use change.

#### *Surfaces*

By definition, artificial surfaces are areas removed from their 'natural' forest or agricultural state, whether they are built, paved or not. They include built land used for residential use or for industrial or commercial use (offices, factories, etc.), paved or stabilized land

(roads, railways, parking areas, roundabouts, etc.), and other areas not built but strongly disturbed by human activity (construction sites, quarries, mines, dumps, etc.). This category also includes artificial green spaces (urban parks and gardens, sports and leisure facilities, etc.). Artificialized surfaces are distinguished from each other by their degree of waterproofing and the nature of the disturbances that their soils have undergone.

It should be noted, however, that some so-called non artificial areas may be completely impermeable and some so-called artificial areas may be completely permeable.

### *The urban footprint*

The urban footprint designates the outline of urban expansion. The broad use of this concept, particularly in approaches that use remote sensing, is explained by its ease of calculation, often based on free Landsat images. Thanks to the availability of high-resolution SPOT images with a panchromatic sensor with 10 m resolution, the limit of this urban footprint has been the subject of a series of analyses in order to better reconcile the statistical and satellite definitions. The urban footprint – a term with a negative connotation, but which refers to the technique of image processing where a greyish spot is perceived – is a major component of land cover and an indicator of land use. It is an important variable in many urban and environmental studies.

The urban footprint does not describe the totality of artificialization since it focuses on the urbanised space, and omits, for example, the extensive transport infrastructure that connects urban areas.

### *Land use change, artificialization*

Artificialization considers the modification of initial surfaces to artificialized spaces (transformed for non-agricultural uses) over a given time step. Several elements can be observed: the location, the type and the pace of these changes. Relatively few examples in the scientific literature involve a comparison of three or more dates, which would allow closer observation of trajectories and growth rates. The limits of such approaches are as much methodological as technical and financial, although the recent free availability of archived images has led to greater interest in time series studies.

## Methods of measurement

Among the various methods that can be used to identify artificialized land and to study land take, the processing of satellite images is widely used. Although remote sensing methods are not created primarily for the measurement of artificialization, they produce data on a European and global scale, and contribute to the understanding of land use. In France, the methods and data used to measure land take within the territory vary according to the scale of implementation (national, regional, local), the scale of objects (from the parcel level to the national level) and the objectives (monitoring exclusive of land take, land use map, aggregation of statistics).