Interactions between land systems and food systems

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Abstract

Interactions between land systems and food systems are central in land system science. Here we highlight three interrelated emerging directions for renewing this research agenda: 1/ What is the role of input providers, and in particular external advisors, financial institutions, and investment modes in shaping farm management decisions?; 2/ Beyond the overall land footprint of distinct production modes and diets, what are the impacts of emerging, rapidly shifting, diet trends?; and 3/ How to grapple with the trade-offs between labor as a substitutable input versus labor as a source of livelihood, and in particular, what is the labor productivity and drudgery of alternative forms of agriculture such as organic farming and agroecology, and how does this balance with the rate of off-farm labor force absorption.

1. Introduction

Land systems (1, 2, Figure 1A) and food systems (3, 4, Figure 1B) intersect and interact in multiple ways. Land use for food production is both a key component of land systems and a central part of food systems at the interface between actors that provide inputs in food systems and those that process and consume food (Figure 2). Interactions and substitutions between these different inputs occur through land use. Inputs to food production consist of land, labor, and capital-based inputs including those requiring energy, and they are associated and provided by different agents.

These intersections between land and food systems are key to many global environmental change, environmental justice and sustainability challenges. The impacts of food systems on land use change, as well as trade-offs and synergies between food production, food security, and environmental sustainability have been central in the land system science agenda over decades. This paper does not aim at synthesizing this whole body of research. Instead, here we adopt an agentic perspective to highlight three directions for further research for improving our understanding of how key actors, i.e. input suppliers, consumers, and laborers, shape the interactions between land systems and food systems. These research directions feed into ongoing normative tensions in sustainability of land systems (5), and been relatively less explored from a land systems perspective. Further works could fruitfully build on the rich literature on these topics from food systems research, human geography, political ecology, agrarian studies, and science and technology studies. As discussed below, these different questions are linked with each other. These three questions are:
1/ Who are the agents that provide inputs to agriculture, and what are their roles and influence?
2/ What are the impacts of emerging, rapidly shifting diet trends on land systems, beyond the overall demand for land use?
3/ What are the interactions between labor and other forms of inputs in land systems, and how can we analyze the trade-offs between labor as a substitutable input versus labor as a source of livelihood?

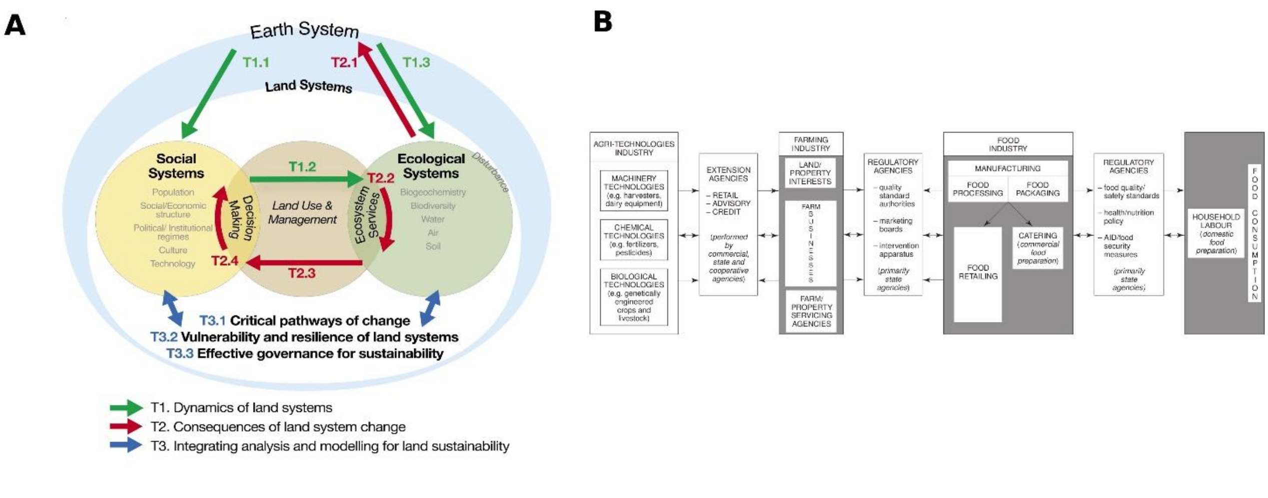

Figure 1: Basic diagrams of land and food systems.
A.: A representation of land systems as social-ecological systems where the human and the environmental components interact through changes in land use, land cover and ecosystem services, from (69). B.: A standard representation of food systems – social-ecological systems encompassing the range of activities related to food –, flowing from inputs and their suppliers on the left towards farming in the middle, and then to processing, distribution, and retailing through the food industry, and diets and consumption patterns, from (70). This does not aim at characterizing subsistence-oriented food systems.

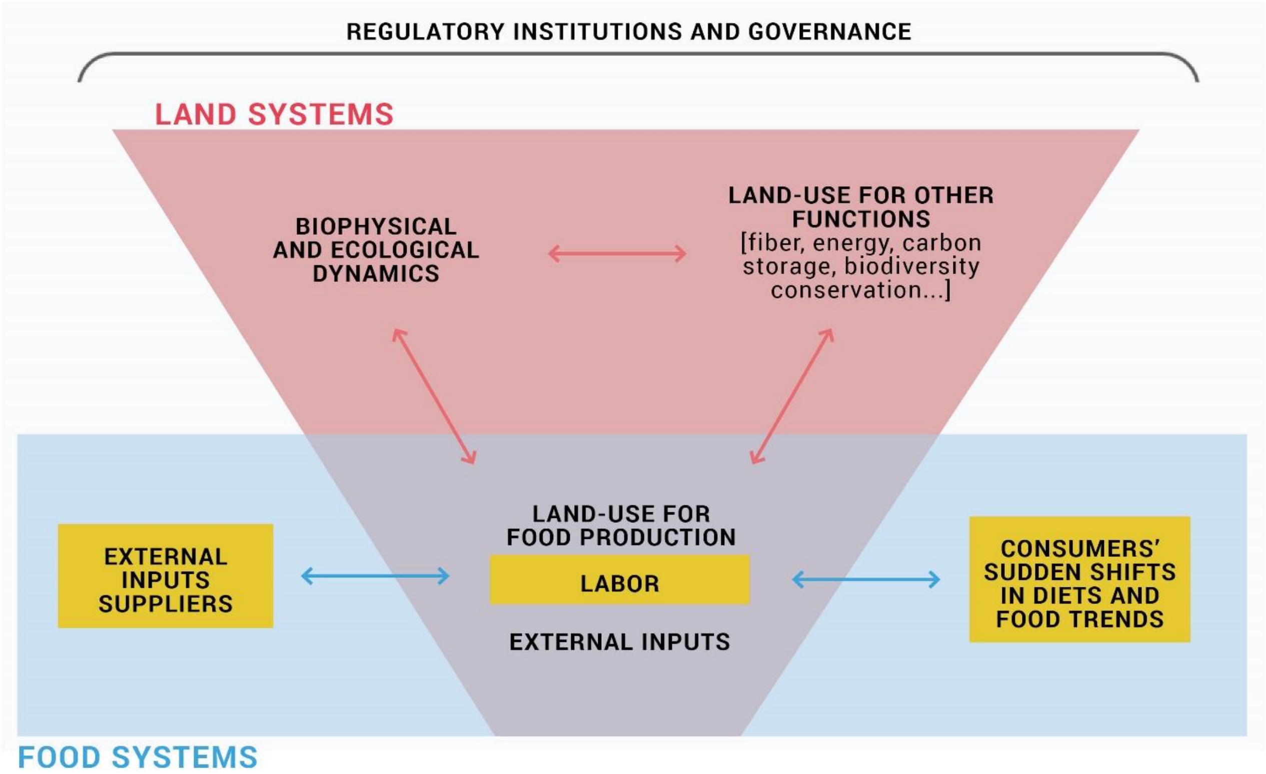

Figure 2: Linkages between food systems and land systems.
Note: The red box represents land systems, composed of diverse land uses, for food production but also other purposes, as well as biophysical and ecological components. Land use for food production constitutes the nexus of interactions with food systems. The blue box represents food systems, with a simplified vision based on Fig. 1B, flowing from inputs on the left towards production in the middle, and then diets and consumption patterns. Highlighted in yellow are the three dimensions of interactions between land and food systems discussed in this paper. Arrows indicate influence.

2. How are input suppliers shaping land use and land-food systems interactions?

Different proportions and combinations of farming inputs, knowledge systems, formal institutions, social norms, values, and cultural preferences determine the form of contemporary agricultural systems. These range from subsistence farms where almost all the inputs are sourced from the farm or its locale to highly mechanized commercial farms that rely heavily on global knowledge networks and input supply chains. Land systems research has explored issues related to the trade-offs different land use modes, such as interactions between smallholder farming and large-scale farming. However, this research rarely takes an agent-based perspective that goes beyond the direct land-use actors (e.g. farmers). The land-use impacts of key actors on the inputs side is poorly understood, in particular extension advisors, input suppliers, and investors. Other key actors, such as transportation agents and infrastructure developers, are not discussed here.

The role of different forms of knowledge (traditional, informal, or formal) and the different advisory and extension service providers (government, non-governmental organizations, consultancies, or agrochemical suppliers) on land-use decision making is a topic that has received little attention in land systems research. There is evidence to believe that over the years, some forms of knowledge and certain agricultural advisory service providers have established dominance over the others. For example, in Europe and the U.S., public sector agricultural advisory roles through universities and governments have been declining due to budgetary constraints in recent decades (6). Meanwhile, advisors from the private sector, who may be independent consultants or work for a range of different agribusiness companies, have been increasing in influence. In Europe, the move to private sector advisors has left a gap for small farms (7). Advisors' level of knowledge and expertise, motives, values, and priorities can vary. For example, approximately 85% of Certified Crop Advisors trained through the American Society of Agronomy are employed by agribusinesses in the US and Canada (Luther Smith, Director of Professional Development and Business Relations, American Society of Agronomy: Personal communication, 2018); thus, in addition to providing agronomic advice, their interactions with farmers may include sales of seed, fertilizers, and chemicals, and certifying the labelling of products based on various standards. Haigh et al. (8) highlight differences in influence and willingness between different types of advisors with regards to mediating conservation and environmental issues.

There is a distinct lack of scholarly research on the role of these agro-chemical and machinery input providers in land systems, from a land system science perspective. Yet, evidence suggests that these agents capture a large share of agricultural value chains (9), and that they are influential actors (10). Some survey research on the perspectives of agricultural advisors have found that those employed by agro-chemical input providers have different perspectives on management of, for example, herbicide resistant weeds (11). Increasingly, farmers are also building on technological inputs for agronomic insight and advice through the use of farm management software and apps on weather conditions and crop growth stage, and the use of drones to monitor farms and fields (12). This brings a whole new set of input providers. The growing role of private actors raises questions about the ownership and use of farm data, as businesses compete for both customers and the data access necessary to improve the tools (13). Although such technologies are mainly used by farmers in the developed world, many free, open source programs and apps are available worldwide, and the increasing role of private advisors and agro-chemical inputs providers is apparent also in the developing world, although the extent of their reach is unknown. Large corporations, such as the main grain producers, are also themselves relying on their network of advisors to collect data and knowledge on farmers' practices, as a way to be able to demonstrate progress towards sustainable sourcing (14, 15). Overall, knowledge on the influence of agricultural input providers on farmers' decision making is more prevalent anecdotally than in the scientific literature.

Another understudied area is the role of agricultural investors and the different types of capital in shaping land use decisions. Studies have investigated the effects of access to credit, remittances and other forms of off-farm income on land use decisions at the farm level (16, 17, 18, 19). Yet, beyond these crude distinctions, very few studies investigated how different forms of credit and investment modes influence land use patterns.

"Financialization" of agri-food systems and its influence on land use is one such topic offering much scope for future research. Financialization comprises several key dimensions; (i) a mode of capital and profit accumulation in which financial channels play an increasingly important role as opposed to commodity trade and production, (ii) the rise of "shareholder value" as a mode of corporate governance in which the property rights of owners and the monetary returns to these shareholders are transcending other forms of social accountability for business corporations, and (iii) the growth and increasing complexity in financial trading through multiple new financial instruments and intermediary activities between savers and the users of capital in the real economy (20). Research on the role of financialization in land systems has been so far mostly framed in the context of transnational investments for "land grabs" and focuses on the implications for small-scale farmers' livelihoods, and food security (21, 22, 23, 24, 25, 26). In the forestry industry, the trends of financialization have been mostly explored in the U.S. (20). But these studies pay very little attention on understanding the decision-making strategies of these investors, and thus on explaining land-use change patterns.

The possibility of abstracting financial activities from real commodities or using property rights for extracting value through rent relations rather than through production has brought in a new set of actors otherwise external to conventional agri-food systems, whose investment motives are now shaped by land and/or commodity speculation. The alleged implications on land value, the extent of acquisitions, ownership, the aggregate effect on land markets, modes of farm operations and the resulting impacts on overall land use and land cover change are yet to be established empirically (27, 28, 29). In addition, these rent relations have created a range of 'assets' previously unknown to agri-food systems and engineered a new set of financial instruments such as weather derivatives, catastrophe bonds, and commodity futures contracts (26). Over the past decade, there has been massive growth in private financial investment by merchant banks, pension funds, and investment companies in these new assets (21), and the financial successes of large grain traders such as the "ABCD" (Archer Daniels Midland (ADM), Bunge, Cargill, and Louis Dreyfus) through the food and financial crisis in partly attributed to commodity-based financial trading (30).

In addition to private equity, another form of capital emerging to influence agricultural systems is 'impact investments' (31). Impact investments are financed mainly by development finance institutions and build on a long history in agricultural development and colonial agricultural ventures. Impact investments are promoted as a more benign form of capital than mainstream investment, balancing the necessity to generate profit with ethical commitments, and is hypothesized to be at times the only source of accessible and patient capital (i.e., capital which has a long-term horizon for profit generation) for small and medium scale farmers and agricultural enterprises (32, 33). Research has only begun to investigate if such impact investments had distinct implications for agri-food systems and land use, especially in the emerging frontier markets (31).

In summary, these different input providers, advisors, and investors with distinct modes of financing create a dynamic landscape that influences who grows what, at which scale, and where, and thus influence the rate and patterns of land use change. An emerging research stream might thus investigate the role of different input providers in shaping farm management decisions and the make-up of contemporary agricultural land systems and patterns of land use change. In particular, how do distinct external advisors, financial institutions, investment modes and access to finance in a region shape the larger context within which food and land systems function and land use decisions are made?

3. Diets, diets, diets – beyond researching no meat, organic, and local

A large body of research focuses on the implications of alternative forms of consumption on land use, energy and greenhouse gas footprints. This research focuses on a few key questions related to the consequences of alternative diets (in particular, more or less animal versus plant-based) and forms of agriculture (in particular, organic versus conventional, and the distance between production and consumption places). Some broad conclusions appear robust. Numerous studies have shown that diets intensive in animal products are more land using. Beef is far more land using than poultry, eggs or dairy products (34, 35, 36, 37), while insects or "cultured meat" developed entirely in the laboratory is the least land using (35). Grass-fed beef is more land extensive than grain-fed beef (36, 38). Organic systems, because of the lower yields on average, are more land using than conventional systems (36, 39). Global-scale implications of broad food system changes, e.g., towards increasingly processed food, or more regionally distinct diets, have also been explored (40).

The major current challenges in assessing land use and other environmental impacts, often through life-cycle assessments (LCA), are (i) to carefully account for potential "hidden" land uses, and (ii) to properly account for trade-offs as the land footprint can be substituted for other equally important environmental concerns. For example, Tuomisto and Teixeira de Mattos (41) estimated that cultured meat offers substantial resource savings compared to conventionally produced European meat, including 99% lower land use, when assuming that the biomass required for the culture medium would come from a novel algae based system. However, when considering a culture medium using conventional livestock feeds, the land footprint for cultured meat would be in line with eggs and poultry, although still lower than beef (35). Similarly, vertical farms have been suggested as a highly land saving form of agriculture, but it may be rather energy demanding due to the use of artificial lights (42).

But another, less studied, dimension of diets and consumption involves shifts in the types of products consumed leading to qualitative changes in land use and associated impacts, beyond the overall quantity of land used. Diets are increasingly influenced by multiple factors including novelty, anticipated health benefits, special dietary requirements or restrictions, and trade protectionism. The agrifood industry has had a longstanding influence on consumers' preferences, but recently, food trends and fashions have been increasingly influenced by social media dynamics (43). The food industry plays on diverse strategies to influence consumers through traditional and social media (44). Sudden shifts in demand for trendy commodities may not have a noticeable impact on global land use, but may have very large and disruptive impacts on land use in localized contexts. Some recent examples include the rapid increase in production of avocado in Mexico and quinoa in Peru and Bolivia in response to global demand (45, 46). The expansion of stevia in China and coconut in Southeast Asia are two other commodities that have been reported widely in the media, but their land use implications remain understudied. Some of these trends have been explored with a perspective focusing mostly on value chains of niche products (47, 48), with still limited understanding of the land system impacts.

We thus suggest here the need for an emerging stream of research exploring: 1/ What are the impacts of novel and emerging trends in diets and consumption patterns on forests, soils, water, land prices, labor and technological innovation demand, livelihoods, and local economies? How do traditional and social media trends influence rapid land-use change related to specific products and locations? 2/ Where and at what levels of intensity are these new crops grown and what are the production methods used? Do these new crops have distinct trade-offs between impacts on land use, energy, GHG, and others environmental dimensions? 3/ What land uses are these new crops replacing? Do these local land-use changes result in global restructuring of production, land use, trade, and marketization patterns?

4. Caught in the middle: Labor intensity, post-fossil fuel agriculture, and livelihoods

While several streams of research explore the linkages between key inputs in land uses and their economic and environmental impacts (49), another fundamental input, labor, is the source of ongoing contention. Debates surround questions on the right amount of labor in farming, and its implications for balancing livelihoods and environmental aspects of sustainability. This debate has been framed in two distinct ways in the literature.

One way is to consider labor as an input among others in the production process. A key issue is the substitutability and actual substitution between land, labor and other inputs derived from capital and external energy (fertilizers, machinery...), related to changing availability and relative costs of these different inputs, which depends largely on factors external to agriculture such as overall energy demand, sectoral shifts and transformations in economies which determine labor demand, and policies. To reduce conversion of natural habitat, diverse forms of sustainable intensification are increasingly explored, which aim to substitute land by other inputs, or raise the Total Factor

Productivity, which is the overall productivity of inputs (2, 50). Excluding land and labor, most other inputs derive from some form of external energy. As mitigating climate change requires reducing the use of fossil energy, sustainable intensification also faces challenges related to the use of these externally-derived inputs. One vision proposes to address this tension by fostering high-energy based land use, powered primarily by nuclear energy, and relying on little labor – essentially, "farming without farmers" (51, 52). Alternatives, such as in the agroecology movement, propose an agriculture mostly powered by human (and animal) labor, and supposed to be much less demanding in external energy (53). Here the trade-offs are essentially between different environmental goals related to land use, including land footprint, overall energy demand, greenhouse gas emissions, and water use.

A second way to frame the debate is to acknowledge that labor is distinct from other inputs, as, beyond its role as a substitutable input in an economic production process, it is a source of livelihoods, also linked to values, lifestyles and aspirations. On the one hand, although farmers value the life and work in farming, in many places farmers and their children aspire for alternatives to escape what they see as the drudgery of farm labor and the isolation of rural lifestyle (54). In developed economies, but also increasingly in emerging economies, shortage of farm labor is a growing challenge. Land uses with high labor demand such as organic farming or horticulture are subsidized by free, precarious or underpaid labor through various schemes (such as volunteers movements, co-op farm shares, students in internships or training programs), underpaid migrant labour, family labor, and off-farm income (55, 56, 57, 58). In these contexts, increasing the labor intensity in land use is unlikely. Yet, in many places, the labor absorption capacity of other economic sectors remains very low, and agricultural transformations create an increasing class of rural landless and urban poor (59, 60, 61). Labor-intensive agriculture would, in these contexts, provide livelihood opportunities, but only if the productivity of labor is sufficient to justify an appropriate wage (62).

Key works have explored the distinction between smallholders-householders, working on their own farm, and farm wage laborers, the former relying on "self-exploitation" of family labor (63). In the context of alternative agricultures, which blur the traditional boundary between family farming and wage labor, a key question is thus to what extent these forms of agriculture are viable when they rely on intensive, tedious labor external to the household. Although nuanced and data-oriented discussions of these issues exist (62-64), we argue that many of the debates on these issues are largely ideological, embedded in modernization thinking versus agrarianist and romantic ethos of farming, and partly because solid data and understanding on several key issues, in particular labor productivity, is lacking. The classic literature argues that labor productivity goes down with intensification unless one shifts to externally-supported agriculture with mechanization and industrial pesticides and fertilizers (2). In contrast, early agroecology literature argued that agroecological techniques would provide high land productivity (accounting for a range of different outputs), but lower labor productivity, which would be desirable as it would ensure a high amount of employment per hectare, keeping people in rural areas and avoiding them having to move to informal jobs in slums (65, 66). Recent studies are more ambiguous, sometimes claiming that agroecology requires lower labor than other forms of agriculture because, basically, "nature does the job" (67).

Providing stronger scientific foundations to these debates requires addressing several inter-related questions, to which the answers are likely to be context-dependent: 1/ Can we produce high amounts of low-cost energy for achieving agriculture with greatly reduced land and labor inputs? Conversely, to what extent do more labor-intensive practices allow to substitute for energy and land? What are the environmental trade-offs between cost-effective farming solutions that increase energy, labor, and land use efficiencies? 2/ What is the labor productivity of different forms of alternative agriculture? And then, to what extent can labor-intensive, less externally-dependent forms of agriculture deliver high labor productivity, which in turn is necessary to support acceptable or desirable lifestyles for farmers as well as the non-farming population and economy? 3/ Beyond mere productivity accounts, do these alternative forms of agriculture reduce the drudgery of farm labor, or enhance it by putting aside mechanization? What is the potential of alternative, labor-intensive farming approaches to fulfill the aspirations to “modern” lifestyles of many young people in rural areas, both in developed and developing countries? What are the prospects for cultural and economic transitions supporting any potential “back to the land” movement? 4/ What is the rate of off-farm labor force absorption with urbanization and sectoral shifts in economies, in different regions and contexts? How does that influence the feasibility of “farming without farmers” approaches, the cost of labor, or the need for social policies to maintain low labor-productivity activities that generate a high amount of employment?

Conclusion

Here, we highlighted three directions for further research for improving our understanding of the interactions between land systems and food systems. These are of course not the only ones. Each of these streams opens research avenues that are valuable in themselves, but these different streams are also linked.

The actors that provide the various inputs used for farming, be they advisors, agro-chemical inputs suppliers, investors, or others, play a key role in shaping the substitution between labor and these other inputs. They also play a key role in shaping the productivity of labor, by mobilizing inputs that can enhance this productivity, or sometimes reduce it. Distinct visions of the role of labor in farming also entails distinct roles for external inputs providers – at one extreme, their role is central as farmers' role in farming would itself become minimal, while at the other extreme these external agents would nearly disappear as farming would become essentially self-reliant.

These inputs suppliers are also constantly monitoring emerging and rapidly shifting diet trends, in order to reorient their inputs towards land uses and regions where their returns may be maximized – be they financial returns, development impacts or others.

Likewise, sudden food fashions also emerge in relation to normative visions of what farming and food ought to be, including in terms of how some consumption trends are supposed to provide better livelihoods to farmers than others and thus should support specific ways of mobilizing farm labor. These emerging diet trends are also embedded in visions of how farming and non-farming populations should interact, including whether and how non-farmers should engage in various parts of the food systems (in financing farming, in contributing to farm labor, etc.). The emergence of new actors, purposes for land use, and tensions around the role of labor also crystallize around the different modes by which claims on land are made and thereby land is access and appropriated (68).

These issues have been explored in various ways in food systems research, human geography, political ecology, and science and technology studies. A land system perspective on these could bring stronger quantitative and spatially-explicit insights on their relation with trends and spatial patterns of land-use change, and their systemic linkages with other aspects of land changes. It would also help to embed these discussions in the broad set of approaches used in land system science including multiple trade-offs analyses across social and environmental dimensions, geospatial analysis, dynamic modelling, and policy evaluation methods. These issues are strongly related to underlying normative visions and assumptions about modernization, and farms and farming as being at the same time a land use resulting in environmental impacts, a way to produce food and fulfill consumer demand, and a means of employment and livelihood. Rigorous research aiming at providing stronger knowledge foundations to the above questions is a prerequisite to overcome ideological lock-ins, i.e., situations where polarized normative positions prevent the possibility of a nuanced debate.

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