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Intensification of Agricultural Systems and their Relation to Production and Efficiency. Results of Application

Review article

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Abstract

Agriculture is facing new challenges, on one hand is the need to increase food production; on the other, a more efficient use of natural resources, biofuels and production of raw materials. Both make agriculture a priority to industrial progress, which have determined new changes in the way intensification processes are implemented to meet the sector´s demands without causing land overuse. This review evaluates the bases for intensification of agricultural systems and their relation to production and efficiency. Additionally, the results from implementation of the Cuban experience are presented. In that context, the current intensification trends were defined, and other different criteria in terms of sustainability were explained. It was concluded that there are different criteria, trends or priorities regarding agriculture intensification; therefore, more than confrontation, conciliation must prevail. The strategy must be directed to an application based on each sector´s particulars, taking sustainability as the common principle of production.

Keywords: *diversification, sustainability, supplies, agroecology*

Introduction

Intensification in agriculture is one of the ways used to enhance production and efficiency. In that respect, Ponssa *et al.* (2010), defined it as increased application of some production factors, while keeping others (land) constant.

It has been associated to management and utilization of inputs, yields, food production and food safety worldwide. Moreover, it has been considered a way to reduce expansion of agriculture over natural ecosystems (Latawiec *et al.*, 2014).

In recent years, agriculture has faced new challenges. López *et al.* (2015), highlighted the need to produce about 70% more foods by 2050, in relation to the population growth estimated, particularly in developing countries. Furthermore, more efficient use of natural resources, biofuels and raw materials production are also added to the new demands, which make agriculture a top sector for industrial development.

The above has determined changes in production strategies, and the way intensification takes place, so they meet the sector´s priorities without land overuse. The aim of this paper is to evaluate the bases of intensification of production in agriculture, and their relation to productivity and efficiency, and disclose the results of their implementation in Cuba.

Development

Intensification in agriculture as a development strategy

According to Herrero and Gil (2008), intensification was started in the 1950s, bringing sustained increases in food production, along with increments in global crop production. The United States began housing most birds by then, and between 1870 and 1980, the same policy was applied to swine and bovines, with high concentrations of animals per area units (Burkholder *et al.*, 2007).

Intensification in agriculture was considered the path of development, characterized by the utilization of large amounts of inputs (fertilizers and other chemicals), mostly from overseas. It meant the development of highly homogeneous technical and mechanized large-scale farms; it was considered by many influential authors as the prevailing scenario in the age of modernity (Sperat and Jara, 2013).

In that sense, Gazzano and Achkar (2014), detailed intensification in agriculture as a transformation of the environmental system, by creating more pressure on the biophysical functions and structures. It configures simpler, more homogenous and particularized systems, in which flow speed increases,the biogeochemical cycles are modified, the system is more open to growing amounts of inputs from external sources, and lower capacity for internal regulations.

The intensive model became global to such extent that it became the basis of "agriculture development", also reaching the industrial countries, with ensuing dependence on inputs and foods, regardless of the impacts on their economies, the environment and their societies, and the risks they were exposed to (Altieri *et al.*, 2011).

According to Altieri and Nicholls (2013), this mode of production has spread out, now covering approximately 80% of the 1 500 billion ha of cropland worldwide. However, it has been unable to suffice international food problems; instead, it has brought concentration and specialization of production, which has led to a marked food unbalance.

Several authors have referred to the effects of the so called high-input intensive agriculture, such as, decrease and loss of biodiversity, destruction of habitats, soil erosion, water pollution, impacts on human health, wealth amassing, foreign land ownership, farmer and family displacements, increase of poverty, etc. (Firbank *et al.*, 2008; Zeigler and Mohanty, 2010; Pingali, 2012).

Unquestionably, this model was irrationalbecause it considered that technology could replace nature, including humans as the dominating species. However, agriculture has long been an area where men and nature come side by side; hence, it is important to foster maintenance and balance of the ecosystems, based on an alternative model to create intensive, more rational, sustainable systems of food production.

A change of paradigm

The effects derived from intensification based on high input use have been self-evident. Nevertheless, FAO (2004) pointed out the need to keep it in present-day and future agriculture conditions. They also added it is necessary to include the effects of climate change and growing competition over lands, water and energy. Accordingly, intensification is a world priority, as a way to overcome the multiple and complex challenges of agriculture in the Twenty-First Century.

In that sense, FAO (2011) suggested a new paradigm for intensive agriculture that relies on environmental sustainability. In essence, it means the blossoming of the *Green Revolution*, using an ecosystem approach based on nature´s role in crop and animal development.

That way, Sustainable Intensification in Agriculture (ISA) emerged as a strategy for agricultural development, which is based on holistic approaches integrated to natural ecosystem process, like soil fertility, pollination, natural pest and disease regulation, and environmentally friendly agricultural practices to increase efficiency and resilience of production systems in agriculture (FAO, 2012).

In accordance with it, the goals for sustainable developmentin 2013 stated by FAO included the following, doubling agricultural production and small farmers´ income; ensuring sustainability of food production systems; applying resilient technologies; keeping genetic diversity, increasing investments (especially in developing countries); and implementing measures to ensure proper function of food markets (Friedrich, 2016) and derivatives.

Garnett and Godfray (2012), said that this global concept of agricultural development is strongly related to agroecology, and it includes efficient use of internal resources and reduction of foreign inputs. Yet, the controversy in terms of ecological intensification and nature-agriculture balance looms.

According to Mahon *et al.* (2017) there is growing interest on the part of governments, research institutions, international organizations and agrobusiness companies in sustainable intensification in agriculture, but they say these practices have not been embraced or well interpreted internationally. These authors have brought debate in several scenarios and international discussions on how it can be measured, what indicators and methodologies can be used for monitoring and evaluation, whether it can be applied to all kinds of agriculture (small, medium, large), and the potential it has.

No doubt, it is a new evolving concept, so there may be questions and answers in that respect. Garnett *et al.*, (2013), on analyzing the premises and policies of sustainable intensification in agriculture said that more is needed to increase sustainability of food producing systems, including the ethnic, social and environmental dimensions.

Furthermore, Titonelli (2014) wondered how far intensification could be sustainable, whether it is not ecological or eco-efficient. The author said there are various criteria in this regard, as questions arise on up to the extent foods will depend on resources, the potential of the system or alternative entries.

The above author also suggested ecological intensification in agriculture, based on intensive sound use of natural support and regulation functions of the ecosystem, through efficient management of biodiversity, solar energy and biogeochemical cycles. It will help restore productivity of degraded soils globally by means of ecological engineering techniques, reduction of losses of resources (water, soils, genes), environmental services, reduction of agriculture´s effects on global warming, pollution, loss of biodiversity, and hunger; productions will target the most widely needed areas (Tintonelli, 2013).

Murgeito, *et al*. (2016), referred to the need of intensification of livestock raising, particularly, forest grazing systems. They pointed the agroecological principles required: increase efficiency of essential biophysical processes that maximize transformation of solar energy in biomass, biological fixation of nitrogen, phosphorous solubilization, accumulation of organic matter on the soil, use of rotational grazing with high stocking rates and long resting periods, utilization of resistant animals used to grazing-browsing in extreme climate; and feeding, proper use of water supply, animal wellbeing, preservation of biological diversity, CO_2 capture, lower CH_4 emissions, high resilience to climatic change, and less use of agrochemicals, hormones and antibiotics.

Regardless of either approach to deal with production in agriculture, the principles that correspond to today´s agricultural development have been well defined and particularized. As a result, there is an evident need to set up systems capable of producing food efficiently, considering the ecology, production and the economy, on sustainable grounds.

In that sense, *Food Sovereignty* is the right of people in their local communities to define and control their own strategies for sustainable production, distribution and consumption. It relies on the diversity of local production modes. The basis of production lies in small and mid-production, which implies questioning industrial foods, respecting each culture´s feeding practices, encouraging local farmers to make decisions locally, controlling their policies and resources to eventually strengthen and consolidate their own modes of production, and marketing and managing (Gómez*et al*, 2016).

Production and efficiency for sustainable intensification in agriculture.

The current approach implemented in agriculture emphasizes productivity and efficiency by fostering production increases that make optimum use of resources and processes within an ecosystem, with high diversification of energy sources and reduction of fossil fuels (Llanos *et al*., 2013).

Vásquez and Funes (2014), noted that when the classic concept of mean productivity has been applied in agriculture, reference has been made of outputs per every input. But these authors also said that the approach is partially applied, because it only deals with one item. Sustainable agriculture, in turn, embraces a diversified intensive approach, which provides stable and diverse biomass production (fiber, foods, fuels, other plants and animals not usually included in statistics, or the analysis of production per soil surface, or energy source used.

Another important issue is the resources used. Ortiz and Alfaro (2014), remarked that "using less to produce more" is not associated with production increases per area unit, but with a more rational use of inputs, especially the least abundant ones (water), or that might harm the environment due to improper use. That way, increasing production based on more resource use is confronted to the unit of inputs employed, which defines the efficiency of a system (Satorre, 2009)

This approach has led to thorough analysis because it considers that along with total system productivity, there must be some room for efficiency, which is the production capacity to generate top outputs with a more rational use of resources (inputs), as defined by Iribarren (2011). In other words, ensuring proper distribution of the means used in relation to the goals set.

In that sense, Funes-Monzote (2009), linked energy efficiency to agrosystems, by defining it as energy efficiency, considering the amount of energy produced and the one used during production. They also noted that energy efficiency is relative to the intensity the internal and external resources are used (low-high input open or closed production models). It was also related to the type of production realized (animal or plant).

The same author combined productivity and efficiency, and recomended a balance of energy needs and benefits for animal and plant production, in order to develop more efficient and productive integrated systems that respond to man´s nutritional, existential and functional needs.

Intensification of sustainable production systems and their results

Various evidence has demonstrated that intensification is feasible when it lies on sustainable grounds. The Institute for Animal Science (ICA) in Cuba, has been working on low-input technologies, including graminaceae growing and managing, and recycling of nutrients in the soil-plant-animal system (Díaz *et al*., 2015).

One of the most effective measures is the establishment of biomass banks (CT-115), which stores feeds in the fields for the dry season (Martínez, 2006). According to Lok *et al.* (2009), biomass banksstudies in dairy farms, improvements were observed in the edaphicproperties and the botanical composition of the areas and the CT-115 population, and milk production increased as well.

Another important alternative for livestock areas is the introduction of legume-improve graminaceae, considering the advantages over the system´s structure and composition. Morales *et al*. (2016) suggested several species achieved through plant breeding (Brachiaria and Pannicum for graminaceae, and Cratylia argéntea, Lablab purpureus, Desmanthus virgatus and Canavalia brasiliensis, for legumes), all considered as potential forages for the dry season.

In that sense, Cruz *et al.* (2015) evaluated intensive bull fattening based on kingrass CT-169 (*Pennisetumpurpureum),* and limited grazing on *Brachiariabrizantha* cv *Marandú*, had daily mean gains of 865 g per animal over a 171 day fattening cycle.

Alonso (2016), noted the positive effects of multiple mixtures with shrub-like or grassy legumes, as a choice to introduce agroecological principles and intensify land use in livestock raising areas, with dairy yields of 10 liters and several economic advantages.

The Indio Hatuey Experimental Station for Pastures and Forages used research done on legume production and use15 years before. It helped develop a technology based on tree-like legumes in forest grazing systems. According to the results, the systems proved a series of economic and ecological benefits in livestock raising, and they are an invaluable alternative that might be critical for the recovery of tropical livestock systems, with direct effects on milk and meat productions (Iglesias et al, 2006).

Other results have been reported by Suárez *et al*. (2014) in the framework of Biomass-Cuba, a project for research on different crops, oriented to integrated food and energy production on ecological agro energy-producing farms. It demonstrated the feasibility of biofuels and foodstuffs using diversified systems.

The Institute for Pasture and Forages Studies also made studies based on production system designs of grazing, use of harvests, crops, derivatives and wastes (livestock raising-agriculture-forestry), known as DIA systems (diversification, integration and self-sufficiency) (Ruiz and Álvarez, 2007).

According to Funes (2007), these systems have produced up to 4-10 t/ha, including plant and animal products, with 11-12 calorie efficiency produced/invested in different Cuban regions, and 10-75% crop inclusion.

The above mentioned papers are models for intensive agriculturalproduction on small and mid-scale farms which can be used for local feed production, under the particular conditions of Cuba, with more than a million and eight hundred thousand hectares of land (Nova, 2016).

The number of private farmers consolidated, especially in CCSs and independent farmers, from 1.5 to 51% land ownership. The best results wereobservedin the farms where there was more use of agroecological practices of production.

Concerning the Cuban experience, Chaparro (2016) said that "the shortages of chemicals, machinery and fossil fuels has been the driving force of a national agroecological movement, in which innovation is present". It was also an experience that motivated, inspired and proved that another type of agriculture is possible. In Cuba "the most outstanding result is the awareness of the benefits of biodiversity and the creation of expertise in design and management of diverse, heterogeneous and complex systems.

CONCLUSIONS

Assessment of the basis of intensification in agriculture revealed the need to consider sustainability as a common principle that must rule production.

Although there are different criteria, trends or priorities regarding agriculture intensification, they coexist as part of food production systems worldwide. Therefore, agreement must prevail over confrontation. The strategy must be directed to application based on the specifics of each sector, including sustainability as the common principle of production.

The Cuban experienceshowed increases in production when sustainable practices were applied to production systems.

REFERENCES

ALONSO, J. (2016). Agro-ecological Principles in Cuban Technologies with Legumes for Animal Production. *Cuban Journal of Agricultural Science*, *50* (2), 171-183.

ALTIERI, M. y NICHOLLS, C. (2013). Agroecología: única esperanza para la soberanía alimentaria y la resiliencia socioecológica. *Agroecología, 7* (2), 65-83.

ALTIERI, M. A.; FUNES-MONZOTE, F. R.yPETERSEN, P. (2012). Agroecologically Efficient Agricultural Systems for Smallholder Farmers: Contributions to Food Sovereignty. *Agronomy for Sustainable Development*, *32*(1), 1-13.

BURKHOLDER, J.; LIBRA, B.; WEYER, P.;HEATHCOTE, S. yKOLPIN, D. (2007). Impacts of Waste from Concentrated Feeding Operations on Water Quality. *Environ. HealthPerspect*, *115*, 308-312.

CHAPARRO, ADRIANA (2016). *Sostenibilidad de los sistemas de producción campesina en el proceso mercados campesinos (Colombia).* PhD thesis , Universidad de Córdoba, España.

CRUZ, MADELÍN; PEREDA, J. y MUÑOZ, D. (2015). Evaluación económica-productiva de un sistema de ceba semi estabulado con pastoreo de *Brachiariabrizantha*cv Marandú en la provincia de Camagüey. *Ecosistema Ganadero,2* (1 y 2), 17-25.

DÍAZ, MARÍAFELICIA; FEBLES, G.; HERRERA, R.; LOCK, SANDRA; MARRERO, YOANDRA; MARTÍNEZ, A; MARTÍNEZ, MARIETA; PÉREZ, TERESA; RODRÍGUEZ, BÁRBARA y VALENCIAGA, DAIKY(2015). *Ciencia e innovación tecnológica. Instituto de Ciencia Animal. Impronta de una idea.*La Habana, Cuba: Ed. EDICA, MES.

FAO (2004). *La ética de la intensificación sostenible de la agricultura*. Estudio FAO, cuestiones de ética. Roma, Italia: Ed. FAO.

FAO (2011). *Ahorrar para crecer. Guía para los responsables de las políticas de intensificación sostenible de la producción agrícola en pequeña escala*. Roma, Italia: Ed. FAO.

FAO (2012). *Intensificación sostenible de la producción agrícola*. Roma, Italia: Comité de agricultura.

FIRBANK, L. G.; PETIT, S.; SMART, S.;BLAIN, A. y FULLER, R.J. (2008). *Assessing the Impacts of Agricultural Intensification on Biodiversity: a British Perspective. The Royal Societyjournal. UK.* Retrieved on June 16, 2016, from http://rstb.royalsocietypublishing.org/.

FRIEDRICH, T. (2016). *Las políticas de FAO en mira hacia una seguridad alimentaria*. Conferencia presentada en el IV Encuentro Internacional Agrodesarrollo, Estación Experimental de Pastos y Forrajes Indio Hatuey, Matanzas, Cuba.

FUNES, F.(2007). *Los recursos fito y zoogenéticos y la agroecología en Cuba.* Tercer Simposio Internacional sobre Ganadería Agroecológica. Memorias SIGA 2007. Instituto de Investigaciones de Pastos y Forrajes, Cuba.

FUNES-MONZOTE, F. (2009). *Eficiencia energética en sistemas agropecuarios. Elementos teóricos y prácticos para el cálculo y análisis integrado*. La Habana, Cuba: Biblioteca ACTAF.

GARNETT, T.yGODFRAY, C. (2012). *Sustainable Intensification in Agriculture. Navigating a Course Through Competing Food System Priorities*. UK: Food Climate Research Network and the Oxford Martin Programme on the Future of Food, University of Oxford.

GARNETT, T.; APPLEBY, M. C.; BALMFORD, A.; BATEMAN, I. J.; BENTON, T. G.*et al.* (2013). SustainableIntensification in Agriculture: Premises and Policies. *Science*, *34*, 33-34.

GAZZANO, I. y ACHKAR, M. (2014). Transformación territorial: análisis del proceso de intensificación agraria en la cuenca del área protegida Esteros de Farrapos, Uruguay. *Bras. de Agroecología, 9*(2), 30-43.

GÓMEZ, E.; MARTÍNEZ, E.; RIVAS, J.A.; VILLALOBOS, E. (2016). La seguridad y soberanía alimentaria. *Revista Iberoamericana de Bioeconomia y Cambio Climático,2* (1), 315-324.

HERRERO, M.A. y GIL, S. (2008). Consideraciones ambientales de la intensificación en producción animal. *Ecología Austral, 18, 273-289.*

IGLESIAS, J.; SIMÓN, L.; LAMELA, L.; D. HERNÁNDEZ, D.; I. HERNÁNDEZ,I.; MILERA, MILAGROS*et al.* (2006). Sistemas agroforestales en Cuba: algunos aspectos de la producción animal. *Pastos y Forrajes*, *29* (3) 217-235.

IRIBARREN, D.; HOSPIDO, A.;MOREIRA, M. and FEIJOO, G. (2011). *Benchmarking* Environmental and Operational Parameters Through eco-Efficiency Criteria for Dairy Farms. *Science Total Environment*, *409*, 1786-1798.

LATAWIEC, A.; STRASSBURG, B.; VALENTIM, F.; RAMOS, F. yALVES-PINTO, H. (2014). Intensification of Cattle Ranching Production Systems: Socioeconomic and Environmental Synergies and Risks in Brazil. *Animal*, *8* (8), 1255-1263.

LLANOS, E.;ASTIGARRAGA, LAURA;JACQUES, R. y PICASSO, V. (2013). Eficiencia energética en sistemas lecheros del Uruguay. *Agrociencia Uruguay*, *17* (2), 99-109.

LOK, SANDRA; CRESPO, G.; TORRES, VERENA; FRAGA, S. y NODA, AIDA (2009). Impacto de la tecnología de banco de biomasa de *Pennisetumpurpureum*Cuba CT-115 en el sistema suelo-pasto-animal de una unidad de producción de leche con ganado vacuno. *Revista Cubana de Ciencia Agrícola*, *43* (3), 307-313.

LÓPEZ, O.; LAMELA, L.; MONTEJO, I. L. y SÁNCHEZ, TANIA (2015) Influencia de la suplementación con concentrado en la producción de leche de vacas Holstein x Cebú en silvopastoreo. *Pastos y Forrajes,38* (1), 46-54.

MAHONA, NIAMH; CRUTEB. I; SIMMONSC, E.; MOFAKKARUL, M.(2017). Sustainable Intensification “Oxymoron” or “Third-Way”? A Systematic Review. *EcologicalIndicators, 74*, 73-97.

MARTÍNEZ, O. (2006). *Bancos de biomasa para la sostenibilidad de la ganadería tropical*. Memorias del curso: Estrategia de alimentación para el ganado bovino en el trópico, Editorial EDICA, Instituto de Ciencia Animal.

MORALES, SANDRA; VIVAS, N.; TERAN, V. (2016). Ganadería eco-eficiente y la adaptación al cambio climático. *Biotecnología en el Sector Agropecuario y Agroindustrial*, *14*(1) 135-144.

MURGUEITIO, E.; BARAHONA, R.; XOCHILT, MARTHA; CHARÁ, J. y ESTEBAN, J. (2016). Es posible enfrentar el cambio climático y producir más leche y carne con sistemas silvopastoriles intensivos. *Ceiba,54* (1), 23-30

NOVA, A. (2016). Economía de la transición agroecológica. (pp. 47-57). En Funes, F. y Vázquez, L. (eds).*Avances de la Agroecología en Cuba*. La Habana. Cuba.

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ORTIZ, R. y ALFARO, D. (2014). *Intensificación sostenible de la agricultura en América Latina y el Caribe*. Montpellier, Francia: Consorcio del CGIAR.

PINGALI, P.L. (2012). Green Revolution: Impacts, Limits and the Path Ahead. *Proc. Natl. Acad. Sci.*,*109* (31), 302-308.

PONSSA, E.;SÁNCHEZ, D. y RODRÍGUEZ, G.A. (2010). *Modelos ganaderos: Intensificación y eficiencia de sistemas productivos.* Argentina: Asociación Argentina de Economía Agraria.

RUÍZ, R. y ÁLVAREZ, A. (2007). *Análisis nutricional de sistemas sostenibles para bovinos en el trópico.* Tercer Simposio Internacional sobre Ganadería Agroecológica, Instituto de Investigaciones de Pastos y Forrajes, Cuba.

SATORRE, E. (2009). *Intensificación y eficiencia en la producción de cultivos: Rol de la nutrición a nivel de sistema*. Simposio Fertilidad 2009. Mejores prácticas de manejo para una mayor eficiencia en la nutrición de cultivos, Centro de Convenciones Metropolitano-Alto Rosario Shopping, Rosario, Argentina.

SPERAT, R. y JARA, C. (2013). Más allá del productivismo capitalista: eficiencia y agricultura familiar en la reactualización de viejos debates teóricos de los estudios agrarios. *de Economía Agrícola, São Paulo*, *60* (1), 53-66

SUÁREZ, J.; MARTÍN, G.; CEPERO, L.; BLANCO, D.; SOTOLONGO, J.; SAVRANVALENTINA, *et al*.(2014). Procesos de innovación local en Agroenergía, orientados a la mitigación y adaptación al cambio climático en Cuba. *Revista Cubana de Ciencia Agrícola*, *48* (1), 17-21.

TITONELLI, P. (2013). Hacia una intensificación ecológica de la agricultura para la seguridad y soberanía alimentaria mundial. *Rev.Ae*., *14*, 10-13.

TITTONELL, P. (2014). Ecological Intensification of Agriculture-Sustainable by Nature. CurrentOpinion in EnvironmentalSustainability, *ScienceDirect*, (8), 53-61.

VÁZQUEZ, L. y FUNES, F. (2014). *Agricultura sostenible sobre bases agroecológicas. Preguntas y respuestas para entender la agricultura del futuro*. La Habana, Cuba: Editora agroecológica.

ZEIGLER, R. S. y MOHANTY, S.(2010). Support for International Agricultural Research: Current Status and Future Challenges. *New Biotechnol*.,*27* (5), 565-557.

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