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Conference Paper

Impact Of Technological Innovations For Coffee Production In Adverse Weather Conditions

53rd Congress of the European Regional Science Association: "Regional Integration: Europe, the Mediterranean and the World Economy", 27-31 August 2013, Palermo, Italy

Provided in Cooperation with:

European Regional Science Association (ERSA)

Suggested Citation: Bliska, Flavia Maria de Mello; Turco, Patricia Helena Nogueira; Vegro, Celso Luis Rodrigues; Fronzaglia, Thomaz; Tosto, Sérgio (2013) : Impact Of Technological Innovations For Coffee Production In Adverse Weather Conditions, 53rd Congress of the European Regional Science Association: "Regional Integration: Europe, the Mediterranean and the World Economy", 27-31 August 2013, Palermo, Italy, European Regional Science Association (ERSA), Louvain-la-Neuve

This Version is available at:

<https://hdl.handle.net/10419/124130>

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IMPACT OF TECHNOLOGICAL INNOVATIONS FOR COFFEE PRODUCTION IN ADVERSE WEATHER CONDITIONS

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A major concern of the Brazilian coffee growers is closely related to the quantitative and qualitative impacts on the coffee sector as a result of possible climate changes, particularly regarding the production of Arabica coffee varieties, which have better beverage quality. This is because low temperatures (below 18 ° C) or elevated (above 23 ° C), causes the blocking of the biological functions responsible for the development of coffee tree, resulting in abortion of flowers and consequently in reducing crop yields and lower grain quality. Moreover, water deficits or poor water distribution (below 1200mm or above 1800mm annually) can also cause damage during flowering and fruiting, and consequent drop in production and in the final product quality. Among the available solutions to minimize the negative effects of climate change, stand irrigation, forestation and new varieties of coffee. Irrigation and trees can be used to circumvent both excess heat and cold as well as to protect the crops from frost. Among the technologies developed at the Agronomic Institute - IAC throughout its 126 years of research on coffee, just stand out studies on irrigation and forestation and development of varieties like Obatã, which has shown good prospects for production in hot regions, traditionally considered marginal for the production of Arabica coffee, since accompanied by irrigation. However, the effects that have been observed with the use of production systems irrigated and shaded, and the cultivation Obatã are not been quantified yet. As a result, this study aims to quantify the environmental, economic and social changes that have resulted from use of those technologies in certain regions of Brazil. To scale the impacts of those technologies we have developed a system consisting of a set of indicators aimed at evaluation of the contribution of technological innovation to environmental, social and economic development of an agricultural activity. The system involves: 1) Collection of data on general technology; 2) Application of questionnaires with selected adopters and entering data on indicators of impact spreadsheets via MS-Excel® platform for obtaining quantitative results and impacts indexes of technology selected; and 3) Analysis and interpretation of indices, which range between -15 and +15. The measurement of these impacts is relevant to the grower, because, as it can know the regional performance of available technologies and make decisions about their possible use, and also for the institutions of Research and Development, which can evaluate and update guidelines of their respective work programs. Among the alternatives coffee production systems analyzed – irrigated, agroforestry, shaded, shaded and irrigated, Obatã cultivar irrigated and Obatã irrigated and shaded – the agroforestry system showed the highest social, economic and environmental impacts indices.

Keywords: Climate change; Impacts of technologies; Sustainable development; Regional development.

INTRODUCTION

In Brazil, coffee is one of the most important crops on the generation of employment and income. Among the major innovations for the production of coffee beans, stand out cultivars adapted to different soil conditions and climate, with good agronomic and technological characteristics, in addition to good quality of beverage. However, the impact of these cultivars made available recently has not been adequately measured, that is, until the moment is not properly valued, in what extent they can actually assist in the transformation of Brazilian coffee production.

Among the newer cultivars, those with resistance to pests and diseases, and especially with multiple resistance, have aroused great sectorial interest. This is because immunity or tolerance to pests and diseases can provide less use of chemicals and therefore significant savings for producers, and significant reduction of risks related to environmental pollution and health of farmers and consumers. Consequently, the innovative characteristics of cultivars with resistance to diseases and pests to meet growing global demand for agricultural production that minimizes waste, unnecessary costs and result in significant and positive impacts on health of workers, farmers and consumers, contributing to sustainable rural development.

However, currently a major concern of the Brazilian coffee growers is closely related to the quantitative and qualitative impacts on the coffee sector as a result of possible climate changes, particularly regarding the production of Arabica coffee varieties, which have better beverage quality. This is because low temperatures (below 18 ° C) or elevated temperatures (above 23 ° C), causes the blocking of the biological functions responsible for the development of coffee tree, resulting in abortion of flowers and consequently in reducing crop yields and lower grain quality. Moreover, water deficits or poor water distribution (below 1200mm or above 1800mm annually) can also cause damage during flowering and fruiting, and consequent drop in production and in the final product quality.

Among the available solutions to minimize the negative effects of climate change, are highlighted the following technologies: irrigation, forestation and cultivars of coffee more adapted to regions with higher temperatures. Irrigation and trees can be used to circumvent both excess heat and cold as well as to protect the crops from frost. These technologies are among those developed at the Agronomic Institute - IAC throughout its 126 years of research on coffee that stand out for showing good prospects for production in warmer regions, traditionally considered marginal for the production of Arabica coffee, since accompanied by irrigation.

However, the effects that have been observed with the use of those technologies, or production system, are not been quantified yet. As a result, this study aims to quantify the environmental, economic and social changes that have resulted from use of those technologies in certain Brazilian regions, where the environmental conditions have some limitations to the coffee cultivation. Climatic conditions of those regions simulate the effects that may result from global climate change on the regions now considered highly appropriate for the coffee cultivation, such as South of Minas Gerais state and Mogiana in São Paulo state.

In summary, with a view to developing programs to protect the coffee activity before possible global climate change, this study estimates the environmental and socioeconomic impacts of the adoption of coffee production systems involving irrigation, forestation and use of new cultivars in the regions West and Chapada/Planalto of Bahia state, Cerrado of Minas Gerais state, Pontal of Paranapanema and Garça-Marília, in São Paulo state.

MATERIALS AND METHODS

To assess the impacts of technologies – irrigation, forestation and new cultivars – we used the *ex post* analysis [1] of four coffee production systems: 1) traditional cultivars irrigated in the West of Bahia state and in Cerrado of Minas Gerais state; 2) traditional cultivars in the shaded system and organic shaded system, in the Chapada and Planalto of Bahia state; 3) Obatã cultivar, in two production systems – irrigated and shaded irrigated – in Garça-Marília, in São Paulo state; and 4) traditional cultivars in agroforestry system, in Pontal of Paranapanema, west region of São Paulo state.

Obatã cultivar (Obatã IAC 1669-20) is considered recent when compared to cultivars that are widely used in Brazil – Mundo Novo and Catuaí. It was registered in 1999 and officially made available to coffee producers in 2000. Mundo Novo cv is used since 1952, when it replaced the Bourbon cv., that prevailed since 1890 until the mid-20th century. Catuaí cv. is planted since 1972. The cultivars Mundo Novo and Catuaí together account for 90.0% of the coffee trees cultivated in Brazil today. This cultivar has short stature, vigorous, short internodes, good secondary branching, young shoots with green color, red fruit, medium to late ripeness, the seeds have average blend of 17, highly resistant to rust. Good quality drink. It is recommended for high density plantations and hedgerow or small-scale. It is a great cultivar for irrigated plantations.

The socioeconomic factors were assessed via Social System of Impact Assessment of Agricultural Technology Innovations (Ambitec-Social) and environmental factors, through the System of Environmental Impact Assessment of Agricultural Technology Innovations (Ambitec-Agro) or System Ambitec [2 - 5].

Ambitec System consists of the ex-post analysis of the impacts of technology, to the extent that it is being conducted after the completion of the research that prompted it. Every aspect of the assessment is covered by a specific methodology. Socioeconomic aspects are evaluated by the Evaluation System of Social Impact of Technological Innovations Agricultural (Ambitec-Social) and environmental impact assessment system through the Environmental Impact Assessment of Agricultural Technology Innovations (Ambitec-Agro).

Together they make up the system Ambitec [9]. Within the Ambitec-Agro, which assesses the environmental aspect, there is Ambitec-Agriculture, Ambitec Animal-Production and Ambitec-Agroindustry. All three are adaptations to environmental assessment of the different segments [2]. The Ambitec is complemented by the Cost Benefit Analysis in the economic dimension, and the generation of jobs in the social aspect. The Ambitec would be the part of the qualitative impact assessment [2].

This system is commonly used in the centers of Embrapa [2-9-13-14]. The Consortium Coffee Research (CBP & D-Coffee) has encouraged its use in the coffee sector, so the results obtained using this methodology can be compared to those obtained by other Brazilian institutions, for their respective technologies coffee, because currently the CBP & D-Coffee embraces about 50 institutions of RD & I.

Ambitec System consists of spreadsheets that consider the contribution of the various aspects of a particular technological innovation for environmental improvement, depending on the agribusiness segment under evaluation. Each of these aspects comprises a set of weighting matrices arranged in automated.

The components of the indicators are rated with coefficients change as personal knowledge of the adopter / guardian of the technology. The application of the system involves an interview / survey conducted by the user of the system and applied to the adopter / responsible for the activity of agribusiness. The interview aims to obtain the coefficient of change of the component, for each of the indicators of impact, as rated by the adoptive / guardian, specifically as a result of application of technology to the activity in the current situation.

The insertion of the coefficients of change, the component directly in the arrays, and sequentially in spreadsheets, automatically results in the expression of the coefficient of the impact of technology, relativized by weighting factors due to the scale of the occurrence of the change and the weight of the component in the composition the indicator. The results are expressed graphically in the spreadsheet "AIA Technology", after the automatic weighting coefficients of change collected data by weighting factors. In the case of Social Ambitec-AIS is the spreadsheet. In summary, the system involves three steps [9]:

- Collection of general information about the technology, including scope (breadth and influence), geographical area and population of adopters (definition of the sample of adopters);
- Application of questionnaires on individual interviews with adopters and insertion of selected data on impact indicators in spreadsheets components of the platform (MS-Excel 1), obtaining quantitative results and impacts of partial indexes and aggregate environmental impact of the selected technology;
- Analysis and interpretation of indices and indication of alternative management practices or technologies to minimize negative impacts and enhance positive ones, contributing to local sustainable development.

The Ambitec-Agro consists of the following criteria (and indicators) for assessment of environmental impacts: the use of inputs and resources (inputs and resources, veterinary inputs and raw materials, energy) and environmental quality (air, soil quality, quality water, biodiversity, environmental remediation). To assess the socioeconomic impacts, in this case the Ambitec- Social, the following criteria and indicators are used: respect for the consumer (product quality, ethical production), employment (training, local employment opportunity and qualified, offer and working conditions, quality of employment), income (income generation of the establishment, diversity of sources of income, value of the property), health (personal and environmental health, occupational health and safety, food safety), management and administration (dedication, and profile of the head, condition of marketing, disposal of waste, institutional relationship).

The evaluation procedure is to ask the adopter/tech responsible for indicating the direction (increase, decrease, or remain unchanged) the coefficients of the components of change for each indicator, due to the specific application of technology to the activity and conditions management for their particular situation. The evaluator informs the adoptive/guardian the aspects and impacts indicators, and survey the unit under evaluation in order to ascertain the quality of the information.

The result of the evaluation depends on the coefficients of the components change, just the subjectivity in its attainment should be reduced by rigorous standardization of the coefficients on the one hand, and his interpretation of another. This standardization is done in two steps: 1) selection and precise formulation of the components and indicators, and 2) delimitation and definition of these components, the technological context. The automatic

matrices include weighting factors relating to the importance of the component for the formation of scale and the geographic indicator of the occurrence of the change in the component. The sum of the weighting is equal to one (1) and varies with the number of components of a given indicator constituting normalization factor as defined in test sensitivity. Since the total amount of all components equal to one (1), the importance of each may be modified to better reflect situations in which certain components must be emphasized.

The scale of the event explains the space in which the change takes place in the component of the indicator, depending on the specific situation of technology application and can be: 1) Spot: the effects of technology are restricted to the place of its occurrence or production unit in which the change is occurring, 2) Local: the effects are felt externally to the production unit, but confined within the boundaries of the property assessment, and 3) In the surroundings: the effects are felt beyond the boundaries of the property.

Due to the highly localized characteristic of some components of indicators, some matrices limit the scope of the occurrence, for example, the use of fertilizers. The weighting factors for the scale of occurrence can not be modified by the user and expresses a value proportionally greater when technology affects an area or an environment that goes beyond the limit of the business unit.

The use of spreadsheets of Ambitec System is simple, flexible and user can adapt them to specific situations [9]. In the environmental dimension, the method provides measures of the contribution of agricultural technology for sustainable local development. The system allows active participation of the producers or responsible and serves for the communication and storage of information on environmental impacts.

The results of the impact assessment are expressed graphically in the worksheet and range between -15 and +15.

The computing platform is widely available, subject to distribution and use at low cost and allows the direct release of printed reports and easy to handle. The graphical presentation of results of environmental performance of technological innovation for each individual indicator provides a diagnostic for the producer or director, pointing to the situation in accordance with environmental standards in every aspect of the impact of technology in terms of the establishment. The graphics of the aggregated results for the different dimensions provide an overview of the contributions, positive or negative, of technology for sustainable site development, facilitating the definition of measures to promote or control the activity within the community and provide an accurate unit measurement of impact.

As the sample size will depend on the universe of adopters, it will be defined during the study, after the identification of the scope, geographical area and population of adopters of each technology to be analyzed. The tests are applied in situ, in regions where the technologies are used.

Geographical area and population of adopters of each production system analyzed

We defined an intentional sample of respondents from the universe of adopters of different coffee production systems, based on the scope and boundaries identified for each one, and, when it was possible, with the following profiles: family and business producers.

Coffee production systems analyzed:

- Irrigated: traditional cultivars (Mundo Novo and Catuaí).

- Irrigated: cultivar Obatã IAC 1669-20 (“new cultivar”).
- Shaded: traditional cultivars (Mundo Novo and Catuaí).
- Shaded: new cultivar (Obatã).
- Shaded: irrigated and new cultivar (Obatã).
- Shaded: agroforestry, traditional cultivars (Mundo Novo and Catuaí).

In total were applied 32 questionnaires of impacts evaluation. The four questionnaires applied in Garça-Marília compared the impacts of irrigated Obatã cultivar with traditional irrigated cultivars in that region.

However, it was also necessary to compare the behavior of irrigated Obatã with the same cultivar without any irrigation system. To do that, we used total impact indices of Obatã not irrigated (analyzed front of Mundo Novo, Catuaí, Tupi and Icatu cultivars), obtained by the same method used in this study – Ambitec-Agro – and for the same Brazilian regions. Those indices are showed in table 1.

Table 1. Impact indices of coffee production (environmental, economic, social), Obatã cultivar, Brazilian regions, conventional production system (not irrigated), Minas Gerais, São Paulo and Bahia states, 2012.

Brazilian state	Region	Number of questionnaires	Impact indices of Obatã not irrigated			
			Environmental	Economic	Social	Total
Minas Gerais	Cerrado	1	0,13	0,89	0,83	0,57
São Paulo	Garça-Marília	2 (average)	0,34	5,13	2,86	2,35
Bahia	Chapada/Planalto (Plateau / Highlands)	1	0,13	0,89	0,83	0,60
	West	0	*	*	*	*

* It was not find Obatã without any irrigation system in this Bahia region.

Source: Adapted from Bliska et al (2012).

Summary of currently soil and climatic conditions of the regions analyzed:

- Cerrado of Minas Gerais: Average annual temperature: 23 ° C (13.3 to 42). Relief: flat, favorable to mechanization. Altitude: 800m to 1300m. Seasons: well defined, with wet summer and mild winter, dry and long. The regular occurrence of dry spells and low soil fertility determine the requirement of irrigation and chemical fertilization, decisive factors for the success of coffee production. Annual rainfall: 1018mm average, maximum 1684, minimum 295mm. Irrigation system: predominantly located, or dripping.
- West of Bahia: Average annual temperature: 24.5 ° C (18 ° to 32 ° C). Geographically it is inserted in the richest water resources in the Brazilian Northeast. Rainfall: average 1100 mm, maximum 1800 mm, but their distribution is not uniform throughout the region, with areas with extremely long periods of drought compared to the regional average. Soils:

sandy to medium textured, with low fertility and clay content ranging 6-16%. Topography: flat, favorable to mechanization. Irrigation system prevalent: center pivot.

- Chapada / Planalto da Bahia: Climate: tropical. Average annual temperature: 20 ° C. Topography: flat or slightly wavy. Rainfall: can reach 1600mm annually, however, producers identify major shift in pluviometric regime in the region over the past 20 years, particularly with respect to the distribution of rainfall (not as much as the total volume of annual rainfall), resulting in prolonged periods of drought and significant negative effect on the coffee production region. Currently there are water shortages in the region and the granting for use of water for irrigated agriculture were suspended by the government. Naturally more fertile soils than in Western of Bahia and Cerrado of Minas Gerais.
- Garça-Marília: Average altitude: 670 m. Temperature: Maximum 31 ° C - 14 ° C Minimum Index Rainfall: 1.300 mm / year. Areas favorable to mechanization. Irrigation system prevalent: dripping. Soils naturally more fertile than those of the Cerrado of Minas Gerais and Western Bahia.
- Pontal of Paranapanema: This region is characterized by sandy soils, extremely degraded by its intensive use, without proper management, which resulted in severe erosion, low fertility and low organic matter content of soils. In addition, the region is subject to periods of high temperatures in much of the year, periods of prolonged drought in some years and risk of frost in others, which hinders the sustainability of farms. Large part of the Brazilian coffee regions now considered excellent for coffee production, as to climatic aspects, may in the future have characteristics similar to those currently existing in Pontal, due to possible global climate change.

RESULTS AND DISCUSSION

The impacts indices of the cultivars analyzed are presented from table 2 to table 19.

- Obatã not result in significant environmental and socioeconomic impacts for regional development of Cerrado region, but its impacts are significant when irrigated, mainly in the Garça-Marília region. Although the temperatures in this region are higher than the average temperature of the regions more favorable to coffee production, the temperature, in the flowering period, does not prevent the proper setting of flowers. However, the success of its cultivation, in areas with under higher temperatures during flowering depend on alternative technologies, such as sprinkler irrigation (center pivot) or forestation.
- The sprinkler irrigation – Pivot Central – is a viable option to reduce local ambient temperature and assist in the setting of flowers and fruits, however is subject to the availability of water. And this availability is limited in most regions where temperatures can be unfavorable to the cultivation of coffee. This situation occurs just now in part of Cerrado of Minas Gerais and part of the Plateau of Conquista, Bahia State. In the case that climate changes affect the availability of water, the irrigation pivot will not be feasible
- Drip irrigation is efficient in crop management and grain filling, but does not contribute in reducing the local ambient temperature therefore does not help in fixing flowers, in regions of high temperature during the period of flowering. In some parts of the Cerrado of Minas Gerais there is no availability of water for irrigation drip regular. Even this type of irrigation is used only in operations known as "rescue or help". For this, farmers need to build dams to collect rain water, which requires the

availability of machinery and financial resources.

- The forestation of coffee plantations has resulted in significant positive impacts. On the Plateau and Chapada of Bahia, forestation began about 30 years, and was conducted with the specie *Grevillea robusta*, aiming to reduce the action of the winds. In the last two decades, changes in rainfall that occurred in that region resulted in damage to coffee yield. However growers observed that the lines of coffee next to lines of Grevillea, therefore more shaded, are less affected by prolonged periods of drought, and maintains productivity level higher than the other plants of the same field.
- The example of forestation with Grevillea took some coffee producers to test other trees, both forests as fruit. At the Chapada of Conquista, Bahia state, are examples of forestation with different species, not just in the conventional system (chemical fertilization and use of pesticides), but also organic system.
- In the region of Garça-Marília, São Paulo State, forestation of coffee plantations is also done with irrigation, especially in the case of Obatã cultivar, and has resulted in positive impacts, but the results are still preliminary. Obatã is considered extremely productive thus is more demanding on nutrients and water, so it is more sensitive to prolonged periods of water shortage. The forestation has been carried out with rubber, which have not yet reached maturity, so there is no information about the behavior of the coffee crop when the rubber trees are in productive age. The expectation is that at least two lines of coffee which flank the rubber trees are could be eliminated.
- Synthesis of dimension impact of these alternative production systems is presented in Table 4. It is observed that the most significant positive economic impacts are obtained under irrigated systems and are particularly higher for cultivars Obatã in the region of Garça-Marília, São Paulo state. However, these economic impacts are accompanied by high negative environmental impacts also significant.
- The economic impact of coffee forested in Plateau of Bahia, although is not so high compared to the irrigated coffees, is accompanied by a positive environmental impact. The big difference with respect to the environmental impacts of irrigated cultivation system and the systems forested (not irrigated) is the energy consumption. The forested non-irrigated does not use electricity or diesel required for irrigation.
- The best alternative in terms of environmental, social and economic, was obtained by means of an agroforestry system in the Pontal of Paranapanema, São Paulo state. But we must remember that this system has been applied on small farms, with hand labor, family, in a region with highly degraded soils by human action, and subject to unfavorable climatic conditions for the cultivation of coffee, both with respect to temperature high at certain times of the year, as with the long periods of drought and the possibility of frost on some occasions. At the same time, environmental conditions currently found in this region can simulate the landscapes that may arise from possible severe climate change. Thus, the agroforestry system could enable the maintenance of the cultivation of coffee in coffee regions that may be affected by climate change.

Table 2. Impact indicators of coffee production in the following production systems: irrigated (Cerrado of Minas Gerais state – MG and West of Bahia state – BA), forested (Chapada and Plateau of Bahia – BA), agroforestry (Pontal of Paranapanema, São Paulo state – SP), irrigated cultivar Obatã (Garça-Marília, São Paulo – SP) e irrigated and forested Obatã (Garça-Marília, São Paulo – SP) and their performance coefficients, Brazil, 2013¹.

Impact indicators of activity	Performance coefficients					
	Irrigated Cerrado MG	Irrigated Oeste BA	Chapada BA Forested	AgroforestrySP	Obatã Irrigated SP	Obatã Irrigated Forested SP
Respondent	-6,1	-3,9	4,3	11,0	-19,7	-1,0
Use of agricultural inputs and resources	-1,4	-0,5	0,0	0,6	-4,0	-0,5
Use of veterinary inputs and raw materials	-7,1	-8,4	0,0	6,3	-30,0	-7,5
Energy use	0,0	0,0	0,0	8,0	0,0	0,0
Atmosphere	-3,8	0,3	6,4	15,0	-15,2	3,8
Soil quality	0,0	0,0	0,3	7,5	0,0	0,3
Water quality	0,0	0,7	0,5	13,3	0,8	0,4
Biodiversity	0,4	0,4	1,2	10,4	1,6	0,4
Environmental restoration	-3,4	0,0	2,0	15,0	-12,7	-3,8
Product quality	0,5	0,0	0,6	4,8	1,8	0,0
Ethics productive	7,1	8,4	5,8	2,8	28,8	6,5
Qualification	2,6	2,9	0,9	3,1	11,7	3,0
Opportunity of local and qualified employment	1,6	0,9	2,1	1,4	6,0	1,4
Supply and working condition	3,1	6,0	0,0	0,0	12,0	2,0
Employment quality	15,0	14,7	10,7	8,6	60,0	15,0
Income generation	15,0	8,5	5,2	4,5	52,6	11,3
Diversity of income sources	13,4	10,4	7,7	10,3	57,0	13,5
Value of property	0,0	0,0	0,2	8,0	0,0	0,0
Environmental and personal health	0,0	0,0	2,1	14,0	0,0	0,0
Safety and occupational health	14,4	10,7	10,3	6,2	57,6	14,4
Food security	13,7	11,7	6,3	4,2	57,0	15,0
Dedication and profile manager	5,8	5,1	4,3	3,8	18,8	2,3
Condition of sales	0,0	0,0	3,9	2,8	0,0	0,0
Waste disposal	8,7	12,7	5,7	1,8	32,0	6,5

Source: Data from the study.

¹ Impact indices ranging between -15 e +15.

Table 3. Integrated impact indices of the following coffee production systems: irrigated (Cerrado of Minas Gerais state – MG and West of Bahia state – BA), forested (Chapada and Plateau of Bahia – BA), agroforestry (Pontal of Paranapanema, São Paulo state – SP), irrigated cultivar Obatã (Garça-Marília, São Paulo – SP) e irrigated and forested Obatã (Garça-Marília, São Paulo – SP) and their performance coefficients, Brazil, 2013¹.

Criteria	Integrated Impact Indices / Coffee Region					
	Irrigated Cerrado MG	Irrigated Oeste BA	Chapada BA Forested	AgroforestrySP	Obatã Irrigated SP	Obatã Irrigated Forested SP
Use of inputs and resources	-4,82	-4,27	1,43	5,95	-4,41	-3,00
Environmental quality	-0,67	0,14	1,68	10,85	-0,63	0,96
Respect for consumers	-1,44	0,00	1,30	9,90	-1,34	-1,88
Employment	3,62	4,63	2,19	1,82	3,65	3,22
Income	14,45	11,08	7,86	7,76	14,13	13,25
Health	4,80	3,55	4,20	9,40	4,80	4,80
Management and administration	7,05	7,31	5,03	3,15	6,74	5,94

Source: Data from the study.

¹ Impact indices ranging between –15 e +15.

Table 4. Environmental, economic and social impacts of technology, and total impacts of coffee production in the following production systems: irrigated (Cerrado of Minas Gerais state – MG and West of Bahia state – BA), forested (Chapada and Plateau of Bahia – BA), agroforestry (Pontal of Paranapanema, São Paulo state – SP), irrigated cultivar Obatã (Garça-Marília, São Paulo – SP) e irrigated and forested Obatã (Garça-Marília, São Paulo – SP) and their performance coefficients, Brazil, 2013¹.

Criteria	Impact index of activity					
	Irrigated Cerrado MG	Irrigated Oeste BA	Chapada BA Forested	AgroforestrySP	Obatã Irrigated SP	Obatã Irrigated Forested SP
Environmental	-2,74	-2,06	1,56	8,39	-2,54	-1,02
Economic	7,75	7,85	5,03	4,79	8,89	8,23
Social	3,47	3,62	3,51	7,48	3,40	2,95
Total	2,94	3,04	3,43	6,74	2,94	3,24

Source: Data from the study.

¹ Impact indices ranging between –15 e +15.

Table 5. Impact indicators of irrigated coffee production system and performance coefficients, Cerrado, Minas Gerais, Brazil, 2013¹.

Impact indicators of activity	Performance coefficients							
	1	2	3	4	5	6	7	Average
Respondent								
Use of agricultural inputs and resources	-5,8	-3,8	-5,8	-9,8	-5,8	-5,8	-5,8	-6,09
Use of veterinary inputs and raw materials	-1,5	-0,5	-1,5	-1,5	-1,5	-1,5	-1,5	-1,36
Energy use	-7,5	-7,5	-7,5	-7,5	-4,5	-7,5	-7,5	-7,07
Atmosphere	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00
Soil quality	-3,8	-3,8	-3,8	-3,8	-3,8	-3,8	-3,8	-3,80
Water quality	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00
Biodiversity	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00
Environmental restoration	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,40
Product quality	-3,8	-1,3	-3,8	-3,8	-3,8	-3,8	-3,8	-3,44
Ethics productive	0,6	0,4	0,6	0,2	0,6	0,6	0,6	0,51
Qualification	8,5	7,5	7,5	8,5	4,0	5,0	8,5	7,07
Opportunity of local and qualified employment	3,0	3,0	3,0	3,0	1,0	2,6	2,9	2,64
Supply and working condition	1,6	1,6	1,6	1,6	1,6	1,6	1,6	1,60
Employment quality	2,0	2,0	2,0	6,0	6,0	2,0	2,0	3,14
Income generation	15,0	15,0	15,0	15,0	15,0	15,0	15,0	15,00
Diversity of income sources	15,0	15,0	15,0	15,0	15,0	15,0	15,0	15,00
Value of property	13,5	11,0	13,5	15,0	13,5	13,5	13,5	13,36
Environmental and personal health	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00
Safety and occupational health	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00
Food security	14,4	14,4	14,4	14,4	14,4	14,4	14,4	14,40
Dedication and profile manager	13,5	13,5	13,5	15,0	13,5	13,5	13,5	13,71
Condition of sales	4,5	6,0	6,0	6,0	6,0	6,0	6,0	5,79
Waste disposal	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,00
Institutional relationship	8,5	10,5	10,5	8,5	7,0	9,0	7,0	8,71

Source: Data from the study.

¹ Impact indices ranging between -15 e $+15$.

Table 6. Integrated impact indices of irrigated coffee production system, Cerrado, Minas Gerais, Brazil, 2013¹.

Criteria	Integrated Impact Indices							
	1	2	3	4	5	6	7	Average
Respondent								
Use of inputs and resources	-4,92	-3,92	-4,92	-6,25	-3,92	-4,92	-4,92	-4,82
Environmental quality	-0,67	-0,67	-0,67	-0,67	-0,67	-0,67	-0,67	-0,67
Respect for consumers	-1,58	-0,43	-1,58	-1,78	-1,58	-1,58	-1,58	-1,44
Employment	3,78	3,53	3,53	4,78	3,15	2,8	3,74	3,62
Income	14,5	13,67	14,5	15	14,5	14,5	14,5	14,45
Health	4,8	4,8	4,8	4,8	4,8	4,8	4,8	4,80
Management and administration	6,63	7,5	7,5	7,32	6,63	7,13	6,63	7,05

Source: Data from the study.

¹ Impact indices ranging between -15 e $+15$.

Table 7. Environmental, economic and social impacts of technology, and total impacts of irrigated coffee production system, Cerrado, Minas Gerais, Brazil, 2013¹.

Criteria	Impact index of activity							
	1	2	3	4	5	6	7	Average
Respondent								
Environmental	-2,79	-2,29	-2,79	-3,46	-2,29	-2,79	-2,79	-2,74
Economic	9,14	8,6	0,01	9,89	8,83	8,65	9,12	7,75
Social	3,28	3,96	3,58	3,47	3,28	3,45	3,28	3,47
Total	2,86	3,12	2,92	3,02	2,99	2,76	2,9	2,94

Source: Data from the study.

¹ Impact indices ranging between -15 e $+15$.

Table 8. Impact indicators of forested coffee production system and performance coefficients, Plateau and Chapada, Bahia, Brazil, 2013¹.

Impact indicators of activity	Performance coefficients							
	1	2	3	4	5	6	7	Average
Respondent								
Use of agricultural inputs and resources	4,3	4,3	4,3	7,5	1,3	4,3	4,3	4,3
Use of veterinary inputs and raw materials	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Energy use	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Atmosphere	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Soil quality	5,0	5,0	5,0	15,0	5,0	5,0	5,0	6,4
Water quality	0,3	0,3	0,3	0,3	0,0	0,5	0,5	0,3
Biodiversity	0,7	0,7	0,7	0,7	0,0	0,0	0,7	0,5
Environmental restoration	1,2	1,2	1,2	1,2	1,2	1,2	1,2	1,2
Product quality	0,0	0,0	0,0	6,3	2,5	2,5	2,5	2,0
Ethics productive	0,8	0,8	0,8	0,8	0,4	0,4	0,4	0,6
Qualification	6,5	6,5	9,0	6,5	4,0	4,0	4,0	5,8
Opportunity of local and qualified employment	0,8	0,8	0,8	1,3	0,8	0,8	0,8	0,9
Supply and working condition	3,0	3,0	3,0	3,0	1,0	1,0	1,0	2,1
Employment quality	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Income generation	15,0	15,0	15,0	15,0	5,0	5,0	5,0	10,7
Diversity of income sources	3,0	3,0	4,5	11,0	5,0	5,0	5,0	5,2
Value of property	6,8	6,8	6,8	10,8	7,5	7,5	7,5	7,7
Environmental and personal health	0,0	0,0	0,0	0,0	0,4	0,4	0,4	0,2
Safety and occupational health	0,0	0,0	0,0	7,5	2,5	2,5	2,5	2,1
Food security	14,4	14,4	14,4	14,4	4,8	4,8	4,8	10,3
Dedication and profile manager	5,8	5,8	4,3	13,0	5,0	5,0	5,0	6,3
Condition of sales	3,8	3,8	3,8	15,0	1,3	1,3	1,3	4,3
Waste disposal	4,0	4,0	4,0	15,0	0,0	0,0	0,0	3,9
Institutional relationship	6,5	6,5	6,5	10,0	3,5	3,5	3,5	5,7

Source: Data from the study.

¹ Impact indices ranging between -15 e $+15$.

Table 9. Integrated impact indices of forested coffee production system, Plateau and Chapada, Bahia, Brazil, 2013¹.

Criteria	Integrated Impact Indices							
	1	2	3	4	5	6	7	Average
Respondent								
Use of inputs and resources	1,42	1,42	1,42	2,50	0,42	1,42	1,42	1,43
Environmental quality	1,43	1,43	1,43	3,43	1,24	1,34	1,48	1,68
Respect for consumers	0,40	0,40	0,40	3,53	1,45	1,45	1,45	1,30
Employment	2,57	2,57	3,19	2,69	1,44	1,44	1,44	2,19
Income	8,25	8,25	8,75	12,25	5,83	5,83	5,83	7,86
Health	4,80	4,80	4,80	7,30	2,57	2,57	2,57	4,20
Management and administration	5,00	5,00	4,63	13,25	2,44	2,44	2,44	5,03

Source: Data from the study.

¹ Impact indices ranging between $-15 e +15$.

Table 10. Environmental, economic and social impacts of technology, and total impacts of forested coffee production system, Plateau and Chapada, Bahia, Brazil, 2013¹.

Criteria	Impact index of activity							
	1	2	3	4	5	6	7	Average
Respondent								
Environmental	1,42	1,42	1,42	2,97	0,83	1,38	1,45	1,56
Economic	5,41	5,41	5,97	7,47	3,64	3,64	3,64	5,03
Social	3,40	3,40	3,28	8,03	2,15	2,15	2,15	3,51
Total	3,62	3,62	3,71	6,60	2,03	2,20	2,24	3,43

Source: Data from the study.

¹ Impact indices ranging between $-15 e +15$.

Table 11. Impact indicators of irrigated Obatã cultivar and forested and irrigated Obatã, and performance coefficients, Garça-Marília, São Paulo, Brazil, 2013¹.

Impact indicators of activity	Performance coefficients					
	Irrigated Obatã					Irrigated and forested Obatã
Respondent	1	2	3	4	Average	
Respondent	-5,8	-2,3	-5,8	-5,8	-19,7	-1,0
Use of agricultural inputs and resources	-1,5	-0,5	-1,5	-0,5	-4,0	-0,5
Use of veterinary inputs and raw materials	-7,5	-7,5	-7,5	-7,5	-30,0	-7,5
Energy use	0,0	0,0	0,0	0,0	0,0	0,0
Atmosphere	-3,8	-3,8	-3,8	-3,8	-15,2	3,8
Soil quality	0,0	0,0	0,0	0,0	0,0	0,3
Water quality	0,0	0,4	0,4	0,0	0,8	0,4
Biodiversity	0,4	0,4	0,4	0,4	1,6	0,4
Environmental restoration	-3,8	-3,8	-3,8	-1,3	-12,7	-3,8
Product quality	0,6	0,0	0,6	0,6	1,8	0,0
Ethics productive	8,5	6,5	7,5	6,3	28,8	6,5
Qualification	3,0	3,0	3,0	2,7	11,7	3,0
Opportunity of local and qualified employment	1,6	1,4	1,4	1,6	6,0	1,4
Supply and working condition	6,0	2,0	2,0	2,0	12,0	2,0
Employment quality	15,0	15,0	15,0	15,0	60,0	15,0
Income generation	15,0	11,3	11,3	15,0	52,6	11,3
Diversity of income sources	15,0	13,5	15,0	13,5	57,0	13,5
Value of property	0,0	0,0	0,0	0,0	0,0	0,0
Environmental and personal health	0,0	0,0	0,0	0,0	0,0	0,0
Safety and occupational health	14,4	14,4	14,4	14,4	57,6	14,4
Food security	13,5	15,0	15,0	13,5	57,0	15,0
Dedication and profile manager	6,0	2,3	4,5	6,0	18,8	2,3
Condition of sales	0,0	0,0	0,0	0,0	0,0	0,0
Waste disposal	8,5	6,5	8,5	8,5	32,0	6,5

Source: Data from the study.

¹ Impact indices ranging between -15 e +15.

Table 12. Integrated impacts of coffee production system of irrigated Obatã cultivar and forested and irrigated Obatã, Garça-Marília, São Paulo, Brazil, 2013¹.

Criteria	Integrated Impact Indices					
	Irrigated Obatã					Irrigated and forested Obatã
Respondent	1	2	3	4	Average	
Use of inputs and resources	-4,92	-3,20	-4,92	-4,58	-4,41	-3,00
Environmental quality	-0,67	-0,59	-0,59	-0,67	-0,63	0,96
Respect for consumers	-1,58	-1,88	-1,58	-0,33	-1,34	-1,88
Employment	4,78	3,22	3,47	3,14	3,65	3,22
Income	15,00	13,25	13,75	14,50	14,13	13,25
Health	4,80	4,80	4,80	4,80	4,80	4,80
Management and administration	7,00	5,94	7,00	7,00	6,74	5,94

Source: Data from the study.

¹ Impact indices ranging between -15 e +15.

Table 13. Environmental, economic and social impacts, and total impacts of irrigated Obatã cultivar and forested and irrigated Obatã, Garça-Marília, São Paulo, Brazil, 2013¹.

Criteria	Impact index of activity					
	Irrigated Obatã					Irrigated and forested Obatã
Respondent	1	2	3	4	Average	
Environmental	-2,79	-2,00	-2,75	-2,63	-2,54	-1,02
Economic	9,89	8,23	8,61	8,82	8,89	8,23
Social	3,41	2,95	3,41	3,83	3,40	2,95
Total	3,17	2,78	2,83	2,99	2,94	3,24

Source: Data from the study.

¹ Impact indices ranging between -15 e +15.

Table 14. Impact indicators of agroforestry coffee production system and performance coefficients, Pontal of Paranapanema, São Paulo, Brazil, 2012¹.

Impact indicators of activity	Performance coefficients						
	1	2	3	4	5	6	Average
Respondent	11,0	11,0	11,0	11,0	11,0	11,0	11,00
Use of agricultural inputs and resources	0,0	0,0	0,0	0,0	0,0	3,5	0,58
Use of veterinary inputs and raw materials	7,0	0,0	7,0	4,5	12,0	7,0	6,25
Energy use	8,0	8,0	8,0	8,0	8,0	8,0	8,00
Atmosphere	15,0	15,0	15,0	15,0	15,0	15,0	15,00
Soil quality	7,5	7,5	7,5	7,5	7,5	7,5	7,50
Water quality	14,0	14,0	14,0	10,0	14,0	14,0	13,33
Biodiversity	10,4	10,4	10,4	10,4	10,4	10,4	10,40
Environmental restoration	15,0	15,0	15,0	15,0	15,0	15,0	15,00
Product quality	4,8	2,0	2,0	6,4	2,0	11,6	4,80
Ethics productive	0,0	0,0	0,0	1,8	0,0	15,0	2,80
Qualification	1,3	1,3	1,3	1,3	1,3	12,3	3,13
Opportunity of local and qualified employment	1,1	1,1	0,4	1,7	1,1	2,8	1,37
Supply and working condition	0,0	0,0	0,0	0,0	0,0	0,0	0,00
Employment quality	11,3	11,3	0,0	7,5	11,3	10,0	8,57
Income generation	3,8	3,8	0,0	4,5	3,8	11,3	4,53
Diversity of income sources	9,0	9,0	6,0	15,0	9,0	13,5	10,25
Value of property	8,4	8,4	8,4	6,0	8,4	8,4	8,00
Environmental and personal health	14,0	14,0	14,0	14,0	14,0	14,0	14,00
Safety and occupational health	10,0	3,0	1,8	10,0	2,4	10,0	6,20
Food security	4,5	1,0	1,0	4,8	1,0	12,8	4,18
Dedication and profile manager	4,3	2,8	0,8	0,0	2,8	12,0	3,78
Condition of sales	2,0	0,0	0,0	4,0	2,0	9,0	2,83
Waste disposal	2,0	2,0	1,0	2,0	2,0	2,0	1,83

Source: Data from the study.

¹ Impact indices ranging between -15 e +15.

Table 15. Integrated impact indices, agroforestry coffee production system, Pontal of Paranapanema, São Paulo, Brazil, 2012¹.

Criteria	Integrated Impact Indices						
	1	2	3	4	5	6	Average
Respondent							
Use of inputs and resources	8,49	7,32	8,49	7,67	9,32	9,07	8,39
Environmental quality	4,3	4,3	1,21	5,09	4,3	9,56	4,79
Respect for consumers	7,96	6,13	5,75	7,8	6,23	11	7,48
Employment	6,88	5,69	5,09	6,59	6,36	9,84	6,74
Income	8,49	7,32	8,49	7,67	9,32	9,07	8,39
Health	4,3	4,3	1,21	5,09	4,3	9,56	4,79
Management and administration	7,96	6,13	5,75	7,8	6,23	11	7,48

Source: Data from the study.

¹ Impact indices ranging between -15 e $+15$.

Table 16. Environmental, economic and social impacts, and total impacts of agroforestry coffee production system, Pontal of Paranapanema, Brazil 2012¹.

Criteria	Impact index of activity						
	1	2	3	4	5	6	Average
Respondent							
Environmental	8,49	7,32	8,49	7,67	9,32	9,07	8,39
Economic	4,3	4,3	1,21	5,09	4,3	9,56	4,79
Social	7,96	6,13	5,75	7,8	6,23	11	7,48
Total	6,88	5,69	5,09	6,59	6,36	9,84	6,74

Source: Data from the study.

¹ Impact indices ranging between -15 e $+15$.

Table 17. Impact indicators of irrigated coffee production system and performance coefficients, West of Bahia state, Brazil, 2013¹.

Impact indicators of activity	Performance coefficients								
	1	2	3	4	5	6	7	8	Average
Respondent									
Respondent	-5,3	-3,8	-3,8	-3,8	-3,8	-3,8	-3,8	-3,8	-3,9
Use of agricultural inputs and resources	-0,5	-0,5	-0,5	-0,5	-0,5	-0,5	-0,5	-0,5	-0,5
Use of veterinary inputs and raw materials	-9,0	-9,0	-4,0	-9,0	-9,0	-9,0	-9,0	-9,0	-8,4
Energy use	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Atmosphere	1,3	1,3	-1,3	-1,3	0,0	5,0	-1,3	-1,3	0,3
Soil quality	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Water quality	0,7	0,7	0,7	0,7	0,4	0,7	0,7	0,7	0,7
Biodiversity	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
Environmental restoration	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Product quality	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Ethics productive	10,0	7,5	10,0	7,5	7,5	7,5	10,0	7,5	8,4
Qualification	3,3	2,5	3,3	2,5	3,4	2,5	3,0	2,5	2,9
Opportunity of local and qualified employment	0,6	0,7	0,9	0,7	2,1	0,6	0,6	0,7	0,9
Supply and working condition	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0	6,0
Employment quality	15,0	15,0	15,0	15,0	12,5	15,0	15,0	15,0	14,7
Income generation	10,0	7,3	10,0	7,3	7,5	8,8	10,0	7,3	8,5
Diversity of income sources	11,0	9,8	11,0	9,8	11,0	9,8	11,0	9,8	10,4
Value of property	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Environmental and personal health	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Safety and occupational health	14,4	8,4	14,4	8,4	8,4	8,4	14,4	8,4	10,7
Food security	12,8	12,8	12,8	9,3	11,3	12,8	12,8	9,3	11,7
Dedication and profile manager	6,5	3,5	7,3	3,5	5,0	5,0	6,5	3,5	5,1
Condition of sales	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Waste disposal	13,5	12,0	12,0	12,0	13,5	13,5	12,8	12,0	12,7

Source: Data from the study.

¹ Impact indices ranging between -15 e +15.

Table 18. Integrated impact indices, irrigated coffee production system, West of Bahia state, Brazil, 2013¹.

Criteria	Integrated Impact Indices								
	1	2	3	4	5	6	7	8	Average
Respondent									
Use of inputs and resources	-4,92	-4,42	-2,75	-4,42	-4,42	-4,42	-4,42	-4,42	-4,27
Environmental quality	0,47	0,47	-0,03	-0,03	0,16	0,16	-0,03	-0,03	0,14
Respect for consumers	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Employment	4,98	4,18	5,05	4,18	4,76	4,76	4,91	4,18	4,63
Income	12,00	10,67	12,00	10,67	10,33	10,33	12,00	10,67	11,08
Health	4,80	2,80	4,80	2,80	2,80	2,80	4,80	2,80	3,55
Management and administration	8,19	7,06	8,00	6,19	7,44	7,44	8,00	6,19	7,31

Source: Data from the study.

¹ Impact indices ranging between $-15 e +15$.

Table 19. Environmental, economic and social impacts, and total impacts of irrigated coffee production coffee, West of Bahia, Brazil 2013¹.

Criteria	Impact index of activity								
	1	2	3	4	5	6	7	8	Average
Respondent									
Environmental	-2,22	-1,97	-1,39	-2,22	-2,13	-2,13	-2,22	-2,22	-2,06
Economic	8,49	7,42	8,53	7,42	7,55	7,55	8,45	7,42	7,85
Social	4,33	3,29	4,27	3,00	3,41	3,41	4,27	3,00	3,62
Total	3,50	2,86	3,73	2,56	2,82	2,82	3,43	2,56	3,04

Source: Data from the study.

¹ Impact indices ranging between $-15 e +15$.

CONCLUSIONS

Among the alternatives coffee production systems analyzed – irrigated, agroforestry, shaded, shaded and irrigated, Obatã irrigated and Obatã irrigated and shaded – agroforestry system showed the highest social, economic and environmental impacts indices.

Thus, we conclude that coffee production in agroforestry system is a significant alternative for regions with marginal climatic conditions for coffee plantations, as well as regions where the natural landscape has been drastically affected by human actions. If future climate changes occur, many regions that today show edaphoclimatic conditions favorable for the cultivation of coffee may provide conditions similar to those currently observed in Pontal of Paranapanema. So, if the problems that currently affecting coffee production in that region are solved or minimized, the solution of future problems will be anticipated.

The second alternative more interesting, considering the economic, social and environmental sustainability, is the forested production system. This system allows for greater security in the volume of coffee produced in house that pushes regions may occur prolonged periods of drought. It reduces the dependency of: 1) availability of irrigation water, 2) water reserves thus lower investments in dams to collect rain water, for example: 3) government licenses for water use; 4) electric or fossil fuels to enable irrigation. The positive socioeconomic impacts are obtained with forested systems, under conditions of significant water stress, when compared to conventional production systems, under the same conditions.

Irrigated production systems achieve excellent yields. Socioeconomic impacts are higher than those obtained in the shaded system. However its viability will depend on the availability of water resulting from potential climate change. The sprinkler irrigation - through center pivot system - can mitigate the local ambient temperature in hot regions, contributing to the higher establishment of flowers, the flowering period of the crop. However, this irrigation system depends on the availability of water more than the in trickle irrigation.

Regarding the use of cultivar Obatã under high temperatures in irrigated production systems, its viability will depend on the availability of water for irrigation. The high yield potential of crop depends on the increased availability of water and nutrients when compared to traditional cultivars, as Catuaí and Mundo Novo.

The decision on which system of coffee production should be used to mitigate the effects of global climate change on production, depend on the availability of water, more than changes in temperature, since the effect on the temperatures may be mitigated with the use of sprinkler irrigation or via forestation or agroforestry system.

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