CONILON Coffee

3rd Edition
Updated and expanded




The Coffea canephora produced in Brazil

Romário Gava Ferrão
Aymbiré Francisco Almeida da Fonseca
Maria Amélia Gava Ferrão
Lúcio Herzog De Muner
TECHNICAL EDITORS

Capixaba Institute for Research, Technical Assistance and Rural Extension
Rua Afonso Sarlo, 160 - Bento Ferreira - CEP: 29052-010 - Vitória-ES - Brasil - Caixa Postal: 391
Telephone: 55 27 3636 9888; 55 27 3636 9846 - coordenacaoeditorial@incaper.es.gov.br | www.incaper.es.gov.br

ISBN: 978-85-89274-32-6
Editor: Incaper
Format: digital/printed
May 2019

GRAPHIC DESIGN, ELECTRONIC EDITING, FINAL ARTWORK AND COVER
Laudeci Maria Maia Bravin

ENGLISH TRANSLATION
Marcelle Gualda Pasolini

CATALOGING
Merielem Frasson da Silva

PHOTO CREDIT
Augusto Barraque, Incaper and authors' collection

EDITORIAL COORDINATION AND PROOFREADING OF STANDARDIZATION
Liliâm Maria Ventorim Ferrão

Incaper - Rui Tendinha Library
International Cataloging Data in Publication (ICP)

C129 Conilon Coffee / technical editors, Romário Gava Ferrão ... [et al.]; english translation Marcelle Gualda Pasolini. - 3 edition updated and expanded. - Vitória, ES : Incaper, 2019.
974p.: il. color.

Translated from: Café Conilon, 2017 - Incaper.
System Required: Adobe Reader
Access mode: https://bibliotecaruitendinha.incaper.es.gov.br/
ISBN: 978-85-89274-32-6

1. Brazil. 2. Espírito Santo (State). 3. Coffee Cultivation. 4. Conilon Coffee I. FERRÃO, Romário Gava (Ed.). II. FONSECA, Aymbiré Francisco Almeida da (Ed.). III. FERRÃO, Maria Amélia Gava (Ed.). IV. DE MUNER, Lúcio Herzog (Ed.). V. Capixaba Institute for Research, Technical Assistance and Rural Extension. VI. Title.

CDD: 633.73

Elaborated by Merielem Frasson da Silva - CRB-6 ES/675

19

Conilon Coffee in Agroforestry Systems

Fabio Murilo DaMatta, Cláudio Pagotto Ronchi, Eduardo Ferreira Sales and
João Batista Silva Araújo

1 INTRODUCTION

Among the 124 species of *Coffea* described (DAVIS et al., 2011), *Coffea arabica* L. (arabica coffee) and *Coffea canephora* Pierre ex *Froehner* (robusta coffee) are the only ones with economic expression in the world market. In recent years, the production of robusta coffee has been increasing, comparatively, more than that of arabica. In 1985, around 25% of the world coffee production was derived from the robusta coffee, and by 2012-2013 this percentage increased to about 40%. In Brazil, and particularly in Espírito Santo, the production of robusta coffee originates from the Kouillou variety, popularly known as Conilon.

Native from tropical regions of Africa, both arabica and robusta have evolved as woody understory species. The first arabica coffee plantations were therefore conducted under shading, through intercropping with larger trees, in order to simulate the natural habitat of the culture. In many situations, however, coffee plants in full sun can produce more than those shaded (FOURNIER, 1988; BEER et al., 1998). As a consequence, shading was abandoned as a regular cultural practice in many regions of the world. In Brazil, for example, this occurred from the 1960s onwards. At the same time, the first commercial conilon coffee plantations were implanted in Brazil, in the State of Espírito Santo, without the adoption of shading.

The main conilon producing region in Brazil is concentrated in the north of Espírito Santo. In a large part of this region, there is an expressive annual water *deficit*, which, together with the irregular distribution of rainfall, promotes a dry period, which lasts for approximately five months, coinciding with the cold season (SIAG, 2006). It is also common the occurrence of summer temperatures associated with temperatures approaching 40 °C, possibly exceeding this level during the critical phase of grain filling, leading to significant decreases in the crops productivity in that region, due to the high degree of grains wilting. In addition, the soils of the region are shallow, with predominantly medium to sandy textures, with low natural fertility and small water retention capacity (ATLAS ...., 2008). These conditions, together with the strong winds and the high evapotranspiration rate, impose on the coffee industry the need to use irrigation, which contributes to the increase in the coffee production cost. In addition, the indiscriminate deforestation that has occurred in the last decades has unprotected the slopes, favoring the erosion process and reducing the rivers flow in drier periods, which often leads to unavailability of water for irrigation.

The strong northeast and southeast winds, which usually occur at the end of the drought period (August), have caused intense damage to Espírito Santo's coffee culture. During this period, non-irrigated crops, weakened by harvesting and pruning and by the long period of water *deficit* (April to August), suffer from significant defoliation, becoming less productive and longer lasting. These factors, combined with the frequent oscillations in the coffee price and the pressure of society for a more sustainable coffee cultivation, have redirected the coffee grower view on the conduct of his crop, especially for aspects related to the use of perennial species that can be intercropped with the coffee, aiming to increase profitability by cultivated area and to minimize the adverse climate effects (particularly drought, high temperatures and winds) on the crop. In this context, in the conilon coffee plantation in the north of Espírito Santo, intercropping has become an increasingly common practice. Intercropping of conilon with fruit trees (papaya and coconut), with forest species of high economic value of their timber (Australian cedar and teak) and with rubber tree have been practiced since the 1980's. It should be noted that coffee is a product very vulnerable to price fluctuations in the international market and surely the diversification is a strategy to maintain or improve the economic balance of the property.

Until recently, the conilon was considered a "marginal coffee", which, coupled with the small amount produced, did not have the same level of technology developed for arabica. Therefore, much of the research information currently available still pertains to arabica coffee. In this chapter, some information about this coffee, presumably extrapolated to the conilon, is used, whenever possible, to insert results originally obtained with the conilon. It was sought to provide inputs to the technician and the coffee grower to make more concious decisions on the adoption of agroforestry systems as a promising alternative to conilon coffee monoculture.

2 INTERCROPPING: SHADING, AFFORESTATION AND AGROFORESTRY SYSTEMS

Due to its origin in shady environments, coffee has traditionally been classified as a typically shade species. However, there may be considerable genetic variation within the genus *Coffea* as to the plasticity or adaptability of coffee responses to irradiance intensity. This plasticity seems to have been satisfactorily exploited in breeding programs and could explain the success of the economic exploitation of coffee plantations both in the shade and in the full sun, according to the edaphoclimatic characteristics of a given region and the producer's technological level. In Brazil, for example, cultivars currently planted, both arabica and robusta, were selected in competition trials conducted under full sun and under wide spacing, and therefore, these cultivars must potentially have adaptations to high irradiance in higher extension than those of cultivars selected for shaded crops (DaMATTA; RENA, 2002; DaMATTA, 2004b).

In Espírito Santo, the conilon coffee cultivation had traditionally been done without association with other shrub or tree crops. On the other hand, it is quite common, especially in small and medium-sized properties, to plant annual crops between the coffee lines, in order to use the soil more rationally during the crop growth. This allows a better level of subsistence and the generation of additional income for the producer, with consequent reduction of the costs of implantation of the coffee plantation. However, once the crop is formed, the intercrop of coffee with annual cultures becomes impractical, at least at the currently recommended spacing.

The association of coffee plants with other trees can be understood as an intercrop of perennial cultures, but receives different denominations, such as "agroforestry system" (AFS) or "coffee tree afforestation". AFSs are forms of use and management of natural resources, in which perennial species (trees, shrubs, palm trees) are used in association with agricultural crops or with animals on the same land, simultaneously or in a temporal sequence (MONTAGNINI, 1992). Other definitions (DUBOIS; VIANA; ANDERSON, 1996) consider that AFS must have at least one forest species and that the association of coffee with citrus, banana or cocoa tree would be merely an intercrop. The broader definition of Montagnini (1992) allows us to consider the coconut and conilon coffee intercrop, for example, as an AFS and a better approximation of the coffee cultivation reality in Espírito Santo, where conilon coffee can be found intercropping with species of agronomic interest.

The use of the terms "shade trees" or "coffee shading" does not allow a correct understanding of the AFS, where the coffee is inserted, or it may cause a narrow understanding only regarding the shading aspect per se. On the other hand, the term 'AFS coffee per se', used to indicate sparse shading covering approximately 20% to a maximum of 50% of the land, may be more appropriate, insofar as other objectives such as latex, fruit or timber production, with the trees associated with coffee, are also contemplated. The shading of coffee plantations would not be the sole objective, but in this case the production diversification also plays a prominent role The same can be applied to the windbreaks, since the trees interfere in the nearby coffee trees, shading them and thus reducing the fall of leaves and flowers and the incidence of diseases, like *Phoma*, but also being able to generate additional products for the farmer. It should be noted, however, that the term "shading" is quite usual, even in the technical environment and will, therefore, be used throughout this chapter, but in a broader sense of AFS.

In short, the adoption of AFSs should generate a moderate shading, improving the environment sustainability and increasing the stability of the coffee production, either by attenuating potentially stressful conditions and consequent depletion of the crops in full sun, or by the microclimate conditions more appropriate to the production, besides allowing the producer to obtain products other than coffee.

3 BIOTIC ASPECTS

Proper selection and management of permanent shade species can reduce the need for labor to considerably control weeds. Shading can alter the composition of invasive species, allowing the propagation of less aggressive species (broadleaf weeds), which results in less competition with coffee trees. In addition, data obtained in Costa Rica showed that weed growth in coffee plantations was virtually eliminated under more than 40% of homogeneous crop shade. The savings resulting from the almost absolute reduction in weed control costs were twice the cost of keeping shade trees pruned twice a year (MUSCHLER, 1997).

In addition to reducing the incidence of weeds, shading also reduces the incidence of cercospora (*Cercospora coffeicola*), *Phoma* and leaf miner (*Perileucoptera coffeella*), but has an opposite effect on the incidence of coffee borer (*Hypothenemus hampei*) and rust (*Hemileia vastatrix*) (BEER et al., 1998) However, these authors mention that shade favors the persistence of biological control agents, such as *Beauveria bassiana* and parasitic wasp (*Cephalonomia stephanoderis*).

The maintenance of high levels of soil organic matter in AFSs helps stabilize nematode populations (*Meloidogyne* and *Pratylenchus* spp.) Below the critical level for coffee cultivation (ARAYA, 1994). At the same time, the reduction of environmental stresses, due to the shading, promotes an increase in coffee tolerance to nematodes. However, a wrong choice of the species to be used for shading could result in an opposite effect, as observed with Inga spp., which may be an alternative host for nematodes which infest the coffee tree (ZAMORA; SOTO, 1976).

Another important aspect of coffee shading in AFSs is the increase in biodiversity, insofar as it preserves the high diversity of organisms, such as birds, arthropods, mammals and orchids (PERFECTO; VNDERMEER; PHILPOTT, 2014). In addition, the use of trees in carbon sequestration has been proposed as means to increase the income of coffee growers (ALVARENGA; MARTINS, 2004), besides guaranteeing them marketing advantages, such as the improvement of environmental sustainability and organic or certified coffee production.

4 EDAPHIC ASPECTS

In afforested coffee plantations, there is improvement or maintenance of soil fertility through increased capacity of nutrient recycling and addition of plant litter. The stability of the soil temperature competes for smaller losses, by nitrogen volatilization. In addition, the soil is better protected against the impacts of rainwater due to the greater rainwater interception due to the greater vegetation cover in the AFS and the greater soil cover due to more abundance of litter. In addition, the water absorption and infiltration capacity is increased, contributing to reduce soil erosion. In general, use (and response) of nutrients in shaded coffee plantations is lower than in full sun, and thus, the use of fertilizers (CARVAJAL, 1984), especially nitrogen ones, can be reduced for the same amount of coffee produced (ALVARENGA; MARTINS, 2004). Moreover, in shaded coffee plantations with leguminous plants, appreciable amounts of nitrogen (~ 60 kg N ha^{-1} $year^{-1}$) can be established, according to data obtained in Costa Rica (BEER et al., 1998), reducing even more the need for nitrogen fertilization.

Inadequate nitrogen fertilization can result in water table pollution with nitrite and nitrate. In the Central Valley (Costa Rica), where about 50% of the water table is under the arabica coffee cultivation, with intense management and under little or no shading conditions, nitrite and nitrate water table contamination occasionally exceeds 10 mg L^{-1} (REYNOLDS, 1991), considered a level of risk to human health (FRAZER et al., 1980). Annual leaching losses, at 60 or 100 cm depth in the soil, vary from 5 to 9 kg N ha^{-1} in shaded plantations, reaching values around 24 kg N ha^{-1} in crops under full sun. Therefore, the use of shade trees has the potential to reduce the water table contamination by nitrate in the areas of intensely managed coffee plantations. The need to reduce pesticide contamination of the environment, which is constantly and intensely used in coffee monocultures, is another strong argument for the use of intercropping of coffee plantations with shade trees.

5 MICROCLIMATE AND ECOPHYSIOLOGICAL ASPECTS

Shading affects not only the availability of light along the coffee tree crown, but also improves microclimate conditions by reducing the extremes of air and soil temperature, reduces wind speed, maintains relative humidity and buffers water availability of the soil (BEER et al., 1998). As a consequence, woody coffee plantations are better protected against the action of the winds and find an environment more conducive to the maintenance of the photosynthesis rates, with obvious reflexes on the production. It should be highlighted that conilon coffee, as in arabica, is particularly sensitive to the action of winds (DaMATTA, 2004a). In addition to its desiccant effect, the wind can cause leaf and flower abscission and damage new buds and flower buds, facilitating the action of pathogenic microorganisms. In fields exposed to the action of winds, the implantation of windbreaks is, in the main, important to guarantee them sustainability and productivity.

Variations in air temperature and relative humidity, and therefore vapor pressure *deficit*, are closely associated with the daily fluctuation of solar radiation. As the day progresses, transpiration at first increases, in response to discrete elevations in vapor pressure *deficit*. However, additional increases in the evaporative demand, as they occur mainly in the afternoon, cause decreases in transpiration, due to the high sensitivity of the coffee stomata to the reduction of relative humidity (MARTINS et al., 2014). The consequent decrease in latent heat dissipation leads to an increase in leaf temperature. Thus, the absolute gradient of water vapor concentration between the inner spaces of the leaf and the adjacent air (the driving force of transpiration) increases, and, to prevent or attenuate the transpiration flow, the stomata is further closed. As a final consequence, the influx of CO_2 to the chloroplasts decreases, and the rates of photosynthesis decrease greatly and, thus, the photochemical use of the incident irradiance is reduced. Increasing the fraction of energy not used in photosynthesis may potentially lead to the appearance of scald in the most exposed foliage. This process systematic repetition, over time, should appreciably reduce the longevity of the coffee plantation. It is also highlighted that, under water deficiency conditions, these answers are more convincing. Since leaf area is lower under water *deficit* , due to lower leaf growth and higher leaf abscission rates, the crown interior is exposed to higher evaporative demand and higher direct solar radiation. Consequently, the scald occurrence, even in the innermost foliage, is exacerbated, thus aggravating foliar abscission and vigor loss of the coffee tree (DaMATTA, 2004b). On the other hand, in shaded coffee plantations, there is a substantial decrease in the vapor pressure *deficit* between the crown and the atmosphere and, in last analysis, in transpiration. In this condition, the absolute vapor pressure gradient between the inner spaces of the leaf and the adjacent air decreases, and transpiration becomes much more dependent on air resistance than on stomatal resistance (DaMATTA; RENA, 2001). In other words, the influx of CO_2 to photosynthesis, insofar as the stomata remains more open, is not accompanied directly and effectively by water vapor loss, in the face of the air resistance contribution to surpass it of stomatal resistance. This should contribute to optimize the water use by the plant (greater efficiency of water use). Especially in regions subject to relatively long periods of drought and/or high evaporative demand, greater efficiency of water use should translate into obvious advantages in coffee production and longevity (DaMATTA, 2004a; 2004b).

The use of trees with a deep root system, such as grevillea (*Grevillea robusta*), can even increase water availability after long dry periods on the superficial soil layers, in order to maintain the water status of the coffee tree, as observed in the southwest of Bahia (MATSUMOTO; VIANA, 2004). Therefore, as long as the intercrop is correctly planned (adequate choice and management of species for afforestation, evaluation of planting density, soil type, thermal and water regimes, etc.), afforestation of coffee crop is viable tree as far as it would reduce water loss through excessive sweating. These considerations also seem valid for the conilon. In conilon coffee trees intercropping with rubber trees planted in line (north-south orientation), Ronchi et al. (unpublished results) observed, in Sooretama/ES, better vigor and higher photosynthesis rates in the coffee trees closer to the lines, probably due to the better hydration of these plants. The authors also found that in a large number of conilon coffee clones, the percentage of wilting reached 8.2% in coffee plants furthest from rubber tree lines (coffee trees in full sun), decreasing to only 2.8% in the coffee trees near the rubber trees (shaded). Matiello and Caldas (1998) also observed that conilon coffee trees were greener and more productive, with larger grains and a lower proportion of wilting than the plants furthest from rubber tree lines. It is emphasized, however, that the use of tree species with a shallow root system (or planted at high densities) can lead to considerable competition for water (and nutrients), limiting the success of wooded coffee plantations, especially in regions with prolonged dry periods.

The use of suitable tree species, under appropriate densities, does not seem to affect or even stimulate coffee production, depending on the region's soil and edaphoclimatic conditions (DaMATTA, 2004a; 2004b). It is emphasized here that empirical observations suggest that there is genetic variability with respect to the tolerance to shading, that is, different clones of conilon respond differently to shading in terms of production. There is at present no concrete information available for a scientific recommendation on which genetic material would be more or less promising for shaded crops. Results of ongoing experiments at Incaper should fill these gaps in the coming years. However, as a generalization, it is observed that, under adequate environmental conditions and intensive use of inputs (irrigation, fertilization, etc.), plantings in the full sun overlap, in terms of production, to the wooded ones (DaMATTA, 2004a). Three factors may compete, at least theoretically, for the production reduction as far as the afforestation extent increases. (i) lower assimilation of carbon by the whole plant due to the reduced availability of light under excessive afforestation conditions; (ii) greater stimulus to the emission of vegetative buds to the detriment of floral buds (CANNELL, 1975); and (iii) reduction of the number of nodes produced by branch (CASTILLO; LÓPEZ, 1966). Considering that the number of nodes formed is the main component of coffee production (CANNELL, 1975), it can be assumed that, by increasing the size of the trees, production would decrease due to the lower number of nodes formed and fewer flower buds per node, especially in locations with environment conditions close to ideal for coffee growing.

Afforestation can significantly reduce biennial variations in coffee production. As discussed by Cannell (1985), the coffee tree produces few flowers in its native shaded environment and, therefore, has not developed, throughout its evolution, mechanisms to maintain its fruit load balanced with the availability of carbohydrates and minerals. In fact, the coffee tree seems to have evolved in order to carry out the filling of all the fruits formed after the fruit expansion phase, as observed in conilon coffee by Ronchi et al. (unpublished results), in Sooretama/ES. According to this line of reasoning, the causes of overproduction in full sun coffee plantations would reside in the profusion of floral initiation, the low natural removal capacity of part of the fruit, and the drain strength (seeds), instead of low photosynthetic rates *per if* (CANNELL, 1985). This overproduction would lead to the plant's reserves exhaustion, severely compromising the growth and production of the following year. This, normally low, would allow the recovery of the stem-root system reserves and the growth rates, again providing suitable conditions for another heavy fruit load in the subsequent cycle of production. As a consequence, the coffee tree in full sun produces irregularly, and, under suitable conditions of cultivation, this irregularity usually follows a biennial pattern. If fruit overload is associated with the dryness of young branches, which is inevitably preceded by death of absorbing and even higher thin roots, after successive biennial cycles, the coffee tree declines, reducing its productive life (RENA; DaMATTA, 2002). Therefore, the use of afforestation, by allowing the reduction of floral buds, should contribute to buffering the biennial production fluctuations, avoiding overproduction and attenuating the plant depletion, allowing satisfactory yields for longer. In economic terms, a higher number of harvests could perfectly compensate, among certain limits, lower average yields per harvest in those places where full sun coffee plants produce more per harvest than afforested coffee plantations (DaMATTA; RENA, 2002). It should be emphasized, however, that in conilon coffee the biennial production is minimized or buffered, within certain limits, compared to that of arabica coffee, by the periodical renewal of the orthotropic rods, by means of an intense and well-planned pruning system.

In coffee crops in full sun and with high production, the occurrence of high temperatures and water deficiency causes beans malformation, resulting in a lower "sieve" and a high percentage of wilting, with a fall in production and, consequently, income. In addition, ripening is accelerated by excess solar radiation and temperature disfavoring the development of the organoleptic properties that bring quality to the beverage. By reducing overproduction and slowing down the maturation process, a well-managed afforestation can mitigate these problems and allow the harvesting of well-formed grains, larger "sieves" and better beverage quality (CARAMORI et al., 2004). In addition, the extension of fruit ripening period, as observed in conilon coffee trees shaded by rubber trees in the north of Espírito Santo (RONCHI et al., unpublished results), may provide more flexibility to harvesting operations.

6 ECONOMIC ASPECTS

The cultivation of coffee in AFSs is almost always controversial subject from an economic point of view. Diversification makes mechanization difficult, while monoculture facilitates coffee management, especially in large areas. It is also worth noting that small farmers have in the intercropping, in small areas, an economic strategy associated with higher production per area, higher return of labor and greater security in periods of low coffee prices. Indeed, in a study conducted in Central American and Caribbean countries, Current (1997) concluded that the AFSs in small and medium sized properties can be quite feasible and should adopt systems and tree species according to local conditions, studied by means of financial analysis tools and, in addition, socio-cultural benefits should be considered.

Shade timber tree species have low production costs and are therefore considered economically viable options for intercropping AFSs. Alternatively, the use of fruit trees or that can be used for the charcoal production are also a viable option compared to some leguminous trees commonly used in the shading of coffee plantations.

The major problem with the intercropping between coffee and timber tree species is their logging for harvesting, which can cause physical damage to the crop. However, depending on the species of tree adopted, such problems can be minimized. For example, logging 29 *Cordia alliodora* trees in arabica coffee crops in Costa Rica resulted in severe crop damage of only 9%, while the remaining 91% of the plants were only slightly damaged, mainly by the tree crowns (SOMARRIBA, 1992). In any case, the losses generated by the logging of the trees in the AFS can be greatly minimized by scheduling tree logging during periods of crop quiescence or in low productivity periods, or even when coffee prices are down in the market. In general, although tree logging causes some physical damage to the coffee plantation, the costs of repairing affected crops are low and promote only small reductions in coffee production, and are easily compensated by the additional gain from the sale of the obtained timber.

The implementation of AFSs requires careful planning and must be kept in mind for the long term. Although the ecophysiological interactions between coffee and other perennial species are already evident in the short term (effects on soil and microclimate), economic results are usually observable in the long term, especially if one of the intercropping products is timber. For this reason, the economic return of the system has to be calculated or estimated for long terms. In this context, it is safe to assume that planting timber trees constitutes a *green saving*: the value “deposited” or “saved” in the product to be obtained from the sale of trees could compensate the reduction in coffee productivity (caused by shading and/or the reduction in the number of coffee plants per hectare). For example, in Rondônia, the bandarra (*Schizolobium amazonicum*), used for the manufacture of laminates, is a tree very intercropped with conilon coffee using 50 to 60 trees per hectare, that can be cut after 8 years of planting, when they reach

45 cm in diameter at the height of the chest. After 13 years of AFS implementation (ten coffee harvests), the cut of 40 bandarras per hectare would yield the equivalent of 30% of the total gross income obtained with the ten coffee harvests (AVILES; LIMA, 1995). On the other hand, in economic intercropping such as coconut or banana, or palm tree producing species, such as peach palm, the economic analysis must be done from the beginning of fruit or palm heart harvesting, and it is possible to establish equivalence rates in relation to coffee monoculture or to the intercropping. For example, Marques (2000) found a 14% increase in coffee yield (first harvest) intercropped with peach palm (spaced 6 mx 2 m), in relation to monoculture, obtaining additional production of 1,708 kg of heart of palm by hectare.

Estimating the costs of intercropping AFSs with coffee plantations should consider the additional implementation costs, such as the purchase of seedlings and planting of trees, as well as additional costs for tree management and pruning. There are other indirect costs, associated with what can not be received with coffee, caused by the competition for water, light and nutrients between the coffee tree and the shade tree or potential physical damages to the coffee, when the timber is harvested. On the other hand, we must consider the economic gains obtained from the trees, in addition to their indirect benefits, especially on the microclimate aspects and *marketing* advantages. This would allow a holistic view of the intercropping as a productive and environmentally sustainable set with a satisfactory economic return. In any case, in order to decide on the implementation of AFSs, three central aspects should be considered: (i) production objective (s); (ii) environmental characteristics; and (iii) the level and quality of inputs available to improve the environmental conditions for coffee (MUSCHLER, 1997). Thus, when the objective is to produce coffee, while at the same time seeking to maintain production stability, biodiversity and the resources conservation, or when it is sought to produce *organic* or certified coffee, or in order to obtain additional products (timer, fruits etc.), AFSs are highly recommended. Considering the marginal environments, of poor soils, with marked declivity, subject to microclimate stresses, such as low water availability and strong winds, AFSs implantation can be very advantageous. In an opposite situation, planting in full sun would be most recommended. In addition, if available chemical inputs (fertilizers, herbicides, etc.), irrigation and selected highly productive clones, plantings in full sun should overlap the afforested ones. The concomitant analysis of these factors should, therefore, indicate the path to be observed by the coffee grower (DaMATTA; RENA, 2002).

7 AGROFORESTRY SYSTEMS WITH CONILON COFFEE IN ESPÍRITO SANTO

According to Sales, Mendez and Carporal (2013a), the AFS identified in the State of Espírito Santo have better chances of success when coupled with appropriate agricultural policies, for example, the Food Acquisition Program (FAP) and the National Program of School Feeding (NPSF). These AFSs have proved useful in meeting the objective of producing food and products in quantity and quality. In situations of declining coffee prices, the intercropping in coffee plantations can guarantee income and would be a step towards a transition to more autonomous systems.

In any case, the conilon coffee cultivation with shade trees is still not very expressive in Espírito Santo. In surveys carried out by Sales and collaborators, in the last ten years (SALES; ARAUJO, 2005; SALES et al., 2013b), it has been verified that the great majority of the intercropped plantations are located in the northern region of the State, and the intercropping with Australian cedar, teak and rubber tree are the most used. Nevertheless, fruit species , such as cashew, coconut and papaya also have occupied a prominent place (Table 1; Figure 1). It has also been verified that the perennial species are cultivated predominantly in the same line of the coffee crop (with the exception of the rubber tree, see Figure 1), obviously to adapt to the management and the cultural treatments used and necessary to the coffee plantation, and that species with medium to rapid growth rates are preferred. In addition, considering the number of properties identified, the main purpose of the intercropping use lies on shading the coffee tree, especially in small properties. However, when considering the coverage (or extent) of cultivated areas, the production of commercial timber (Australian cedar and teak) and latex (rubber) production encompasses more than 70% of the areas intercropped with conilon coffee. In addition to these purposes, the production of timber for own property, of firewood and fruits, and the formation of windbreaks were also reported by the coffee producers. It should be noted that papaya, in particular, has been used to amortize the cost of coffee implementation. Since the spacing of both crops (coffee and papaya) coincide, especially between the planting lines, the coffee crop is planted in the papaya line, simultaneously or a few months after this culture implantation. Thus, the coffee tree "shares" the culture treatments (mainly fertilization and irrigation) given to the papaya crop, in addition to being opportunely benefited by the shading promoted by the papaya plants.

Table 1. Survey of coffee conilon areas intercropped with trees in the State of Espírito Santo

(to be continued)

Common name	Scientific name	Spacing[1] (m)	Municipality	Total area (ha)/ (number of properties)	Uses[2]	Growth rate
Cashew tree	*Anacardium occidentale*	10 x 12	Vila Pavão	5.0 - (1)	a, e	Average
Coconut tree	*Cocos nucifera*	9 x 8	São Gabriel da Palha	4.5 - (1)	a, e	Average
Australian cedar	*Toona ciliata*	3 x 3 and 15 x 9 m	Jerônimo Monteiro and Sooretama	31.0 - (2)	b, d	Fast
Silky oak	*Grevillea robusta*	3 x 6 m and several	Vila Pavão	0.2 - (1)	a, g	Average
Inga	*Inga sp.*	9 x 6 and 11 x 10 m	Iconha, São Domingos do Norte	1.2 - (2)	a, d	Fast
Nim Indian	*Azadirachta indicates*	6 x 6 m	Vila Valério	1.0 - (1)	a	Average
Peroba	*Paratecoma peroba*	Several	Alegre	1.5 - (1)	b	Slow

(conclusion)

Common name	Scientific name	Spacing[1] (m)	Municipality	Total area (ha)/ (number of properties)	Uses[2]	Growth rate
Rubber tree	*Hevea brasiliensis*	3 x 10 to 10 x 10 m (SL) 18 x 4 x3 m (DL)	Vila Valério, São Gabriel da Palha	23.4 - (5)	a, f	Average
Teak	*Tectona grandis*	8 x 8 m	Sooretama	30.0 - (1)	b	Fast
Achiote	*Bixa orellana*	6 x 3 m	São Gabriel da Palha	4.0 - (1)	a, d, e, g	Fast
Fruit, Timer and Rubber	-	2 x 2 a 12 x 10 m, and several	São Gabriel da Palha, Nova Venécia, São Domingos do Norte, Rio Bananal	13.8 - (11)	a, b, e, f	Fast average
Total	-	-	-	**115.6 - (27)**	-	-

Source: Sales and Araujo (2005).

[1]SL, single line DL, Double line.

[2]Shading (a), commercial timber(b), timber for property (c), firewood (d), fruit production (e), latex production (f) and windbreaks (g).

Note: The data of this survey were obtained through structured questionnaires, applied to the farmers, in the different municipalities, by the extensionists of Incaper from each municipality.

7.1 THE AGROFORESTRY SYSTEMS VIEW UNDER THE PRISM OF FARMERS AND TECHNICIANS

Considering the complexity of AFSs through the association of social, cultural, economic and technical factors, it is imperative to clarify details of these systems in the State of Espírito Santo, so that success cases are understood and AFSs can achieve the desired objectives. To obtain information about these systems, Sales et al. (2013b) visited and interviewed 58 families and 14 technicians working with the AFS in the State. The interviews, conducted between December 2009 and February 2010, aimed at capturing farmers 'and technicians' perceptions on the shift to intercropping production systems. Coffee crop intercropping were evaluated with: timber trees, rubber trees, papaya trees and/or other fruits, etc.

Of the farmers interviewed, 64% were satisfied with AFS practices. According to them, soil cover with crop residues provides protection and could retain soil moisture for longer. There was a preference for planting fast-growing trees. The possibility of working in the shade was also pointed out as an additional factor for the adoption of AFSs. Some farmers reported that they did not pay attention exclusively to coffee as they got a better economic return from other products. In addition, farmers showed that they made little money from coffee production. The interviews were conducted at a time of relatively low coffee prices, which should have accentuated this perception. In contrast, 21 farmers among the 58 interviewees reported reasons for failure and dissatisfaction with AFS trials, such as competing coffee trees for water, light and nutrients, and the consequent reduction in coffee production, resulting in poor performance of the crop. Uncertainty about the future, such as the right to cut the trees planted or to obtain a crop with satisfactory prices for intercropped products, was also highlighted in the interviews. Even with this discouragement, some farmers still believed in diversification. By exposing these farmers, the system was not economically viable due to the high demand for labor, leading them to use chemical fertilizers and herbicides to try to increase revenue and work capacity.

Figure 1. Conilon coffee intercropped with some forest or fruit species: double line of rubber trees (A); one year old teak (B); coconut tree (C); Australian cedar (D); papaya tree and Australian cedar (E); formed cropping - coffee, papaya and Australian cedar (F).

Concerns about AFSs were also shared by most of the 14 technical professionals interviewed. Some of them questioned, even, the recommendation of the AFSs, pointing out problems with the system management. According to some technicians' explanations, the production of coffee plants without adequate fertilization began to decline to the point where farmers returned to conventional systems. In the same way, the trees introduction without adequate management in the coffee cultivation was used in this change, compromising, in some cases, the coffee production. On the other hand, when pruning the trees, the system showed a better compatibility among the species planted. It was also pointed out that, in the northern region of the State of Espírito Santo, trees competed even more with coffee because of periodic droughts. In drought years associated with the fall and winter period (from April to September), which matches the time of the coffee harvest, the crops vigor was compromised.

From the foregoing, the positions of farmers and technicians varied. However, a commitment was observed with the farmer, that is, the co-responsibility in the agroecological transition process. The cautious recommendation of AFSs was considered by some and the rejection of some aspects was adopted by others. In short, the need for better interaction between technicians and farmers to find more viable systems was evident. Part of these controversies well illustrates the lack of scientific information based on the recommendation, or not, of AFSs in Espírito Santo.

7.2 SOME EXPERIMENTAL RESULTS WITH AFSS

Few research projects have been conducted to evaluate the sustainability and adequacy of AFSs in Espírito Santo. Some studies have shown an improvement in microclimate conditions in intercropped plantations. For example, Pezzopane et al. (2011) studied the conilon coffee intercropping with dwarf coconut in São Mateus/ES and verified an attenuation of solar radiation, a reduction in wind speed of up to 35% and a reduction of up to 1.7 ^{o}C in the maximum temperature in the afforested system in relation to that in full sun. In a conilon coffee intercropping with rubber trees, in Jaguaré/ES, Partelli et al. (2014) also observed a decrease in microclimate conditions, especially in coffee trees near the rubber tree, with decreasing temperature and irradiance and increasing relative humidity. According to these authors, the proximity of the coffee tree to the rubber trees increased the length of the plagiotropic and orthotropic branches and the individual leaf area, but without affecting the nitrogen (N), potassium (K), magnesium (Mg), iron (Fe), Zinc (Zn) and Boron (B) concentrations in coffee.

Regarding production, fast-growing timber species such as teak and Australian cedar can compete with coffee, especially in terms of water and nutrients, restricting vigor and crop production (SALES et al., 2013a). Slower growth species, such as the cariniana and the rubber tree, have little or no effect on coffee production (SALES et al., 2013a; PARTELLI et al., 2014). By the experimentation presented, the production of timber proved viable, however, new species should be tested, mainly using other species native from the Atlantic Forest Biome. It is noticed the need to implement more intercropping of coffee trees with other species, since there is a great demand for fruits, latex, timber and environmental services.

Some studies on the intercropping between conilon coffee and peach palm have been developed at the Bananal do Norte Experimental Farm in Pacotuba, Cachoeiro do Itapemirim/ES. The results obtained, however, are contradictory. Marques (2000), for example, testing several peach palm spacing associated with the conilon coffee tree, obtained a 14% increase in coffee yield (first harvest) intercropping with peach palm (spaced 6 mx 2 m), in relation to monoculture and reached further production of 1.708 kg of palm heart per hectare. Similar results were obtained by Brum et al. (2007), who also tested the intercropping with peach palm planted between the lines of coffee, at variable spacing, and observed higher conilon production when the peach palms were spaced 6 mx 2 m. However, Souza et al. (2009), in the same experimental area, observed completely contrasting results, as the shading of peach palm, also in the spacing of 6 mx 2 m, resulted in a marked reduction (greater than 50%) in coffee production compared to that of monoculture. In fact, the data of Souza et al. (2009) point to a linear decrease in coffee production with increasing shading associated with densities of peach palm growing plantings. In any case, it should be noted that in all these studies only one harvest was evaluated and, obviously, the data can not be extrapolated for the long term. In addition, it is likely that any potential positive effect of shading on coffee production, when observed in the early harvests, may be reduced or become negative over time, as the coffee tree crown develops and the self-shading intensifies.

Ronchi, Pereira and Fonseca (2007) studied the effect of shading promoted by rubber trees on the maturation pattern of 31 conilon coffee clones. Compared to coffee trees grown in the full sun, shading delayed or prolonged the maturation period of the fruits of conilon coffee clones, especially those of late maturation. These results corroborate data obtained in arabica coffee, a fact that can provide the collection of larger fruits and with better physical and sensory characteristics than the fruits of plants in full sun (DaMATTA et al., 2012), with possible reflections on the beverage quality.

8 FINAL CONSIDERATIONS

Despite its origin in shaded environments, it seems to have considerable phenotypic plasticity of the coffee tree in response to the light availability. The use of afforestation, with the consequent attenuation of the incident solar radiation, the temperature and the evaporative demand, can result in better conditions for the maintenance of the gas exchanges, with positive effects on the production, particularly in marginal regions to coffee cultivation, characterized for suffering from temperature extremes and/or water deficiency. AFSs, although properly managed, can be associated with market advantages and improved environmental sustainability, as well as providing the producer with insurance against price fluctuations in the coffee market.

Despite the above considerations, very little progress has been made, on a scientific basis, on the understanding of the social, cultural, technical and economic aspects involved in AFSs. There are no clear results from the research for the recommendation of more promising species for shading, no more promising conilon coffee materials have been selected for the shaded culture. Responses to simple but fundamental questions such as how much is spent, how much is earned and how much is saved in terms of resources invested in AFSs involving conilon coffee are virtually non-existent. Multidisciplinary approaches are therefore imperative to understand with the necessary depth the high complexity of these systems. Ultimately, this will allow to understand the success stories of AFSs, generating fundamental information that will guide the adoption of these systems in order to guarantee greater environmental sustainability and greater economic returns for the producer.

9 REFERENCES

ALVARENGA, M. I. N.; MARTINS, M. Fatores edáficos de cafezais arborizados. In: MATSUMOTO, S. N. (Ed.). *Arborização de Cafezais no Brasil*. Edições UESB, Vitória da Conquista, BA: p. 43-84, 2004.

ARAYA, M. Distribución y niveles poblacionales de *Meloidogyne* spp y *Pratylenchus* spp en ocho cantones productores de café en Costa Rica. *Agronomia Costarricense*, v. 18, p. 183-187, 1994.

AVILES, D. P.; LIMA, A. C. Sistemas agroflorestais envolvendo café (*Coffea canephora*) e bandarra (*Shizolobium amazonicum*) no Estado de Rondônia. In: CONGRESSO BRASILEIRO DE PESQUISAS CAFEEIRAS, 21., 1995. Poços de Caldas. *Trabalhos apresentados*... Rio de Janeiro: MAA/Embrapa, p. 183-184. 1995.

ATLAS do ecossistema do Espírito Santo, Vitória, ES: SEMA, Viçosa, MG: UFV. 2008, 504 p.

BEER, J.; MUSCHLER, R.; KASS, D.; SOMARRIBA, E. Shade management in coffee and cacao plantations. *Agroforestry Systems*, v. 38, p. 139-164, 1998.

BRUM, V. J.; BREGONCI, I. S.; CAMPOS, L. P. de A.; REIS, E. F.; AMARAL, J. A. T.; JESUS JUNIOR, W. C. de. Produtividade do café conilon em monocultivo e sombreado com pupunheira. *Revista Brasileira de Agroecologia*, v. 2, p. 1200-1203, 2007.

CANNELL, M. G. R. Crop physiological aspects of coffee bean yield: a review. *Journal of Coffee Research*, v. 5, p. 7-20, 1975.

CANNELL, M. G. R. Physiology of the coffee crop. In: CLIFFORD, M.N.; WILLSON, K. C. (Eds.). *Coffee*: Botany, Biochemistry and Production of Beans and Beverage. London: Westport Conn Helm, p. 108-134. 1985.

CARAMORI, P. H.; KATHOUNIAN, C. A.; MORAIS, H.; LEAL, A. C.; HUGO, R. G.; ANDROCIOLI FILHO, A. Arborização de cafezais e aspectos climatológicos. In: MATSUMOTO, S.N. (Ed.). *Arborização de Cafezais no Brasil*. Vitória da Conquista, BA: Edições UESB, p. 19-42. 2004.

CARVAJAL, J. F. *Cafeto*: cultivo y fertilización. Instituto Internacional de la Potassa, Berna, 1984, 254 p.

CASTILLO, Z. J.; LÓPEZ, A. R. Nota sobre el efecto de la intensidad de la luz en la floración del café. *Cenicafé*, v. 17, p. 51-60, 1966.

CURRENT, D. Los sistemas agroforestales generan beneficios para las comunidades rurales? Resultados de una investigación en América Central y el Caribe. *Agroforesteria en las Américas*, v. 4, p. 21-24, 1997.

DaMATTA, F. M. Ecophysiological constraints on the production of shaded and unshaded coffee: a review. *Field Crops Research*, v. 86, p. 99-114, 2004a.

DaMATTA, F. M. Fisiologia do cafeeiro em sistemas arborizados. In: MATSUMOTO, S. N. (Ed.). *Arborização* *de Cafezais no Brasil*. Vitória da Conquista, BA: Edições UESB, p. 85-119. 2004b.

DaMATTA, F. M.; RENA, A. B. Tolerância do café à seca. In: ZAMBOLIM, L. (Ed.). *Tecnologias de Produção de Café com Qualidade*. Viçosa, MG: Universidade Federal de Viçosa, Viçosa, p. 65-100. 2001.

DaMATTA, F. M.; RENA, A. B. Ecofisiologia de cafezais sombreados e a pleno sol. In: ZAMBOLIM, L. (Ed.). *O Estado da Arte de Tecnologias na Produção de Café*. Viçosa, MG: Universidade Federal de Viçosa, p. 93-135. 2002.

DaMATTA, F. M.; CAVATTE, P. C.; MARTINS, S. C. V. Coffee physiology: growth, yield and quality. In: OBERTHÜR, T.; LÄDERACH, P.; JURGEN POHLAN, H. A.; COCK, J. A. (Eds.). *Specialty coffee: managing quality*. Norcross: International Plant Nutrition Institute, p. 71-87. 2012.

DAVIS, A. P.; TOSH, J.; RUCH, N.; FAY, M. F. Growing coffee: *Psilanthus* (Rubiaceae) subsumed on the basis of molecular and morphological data; implications for the size, morphology, distribution and evolutionary history of *Coffea*. *Botanical Journal of the Linnean Society*, v. 167, p. 357-377, 2011.

DUBOIS, J. C. L.; VIANA, V. M.; ANDERSON, A. B. *Manual Agroflorestal para a Amazônia*. Rebraf, Rio de Janeiro: v. 1., 228 p., 1996.

FOURNIER, L. A. El cultivo del cafeto (*Coffea arabica* L.) al sol o a la sombra: un enfoque agronómico y ecofisiológico. *Agronomia Costarricense*, v. 12, p. 131-146, 1988.

FRAZER, P.; CHILVERS, C.; BERAL, B.; HILL, M. J. Nitrate and human cancer: a review of the evidence. *International Journal of Epidemiology*, v. 9, p. 3-11, 1980.

MARQUES, P. C. Utilização de palmáceas produtoras de palmito, para sombreamento de café conilon, no Estado do Espírito Santo. In: SIMPÓSIO DE PESQUISA DOS CAFÉS DO BRASIL, I., 2000, Poços de Caldas. *Anais*... Brasília, DF: Embrapa Café, p. 1772-1773. 2000.

MARTINS, S. C. V. ; GALMÉS, J.; CAVATTE, P. C. ; PEREIRA, L. F.; VENTRELLA, M. C.; DaMATTA, F. M. Understanding the low photosynthetic rates of sun and shade coffee leaves: bridging the gap on the relative roles of hydraulic, diffusive and biochemical constraints to photosynthesis. *Plos One*, v. 9, 2014.

MATIELLO, J. B.; CALDAS, S. F. B. Sombra vertical ou itinerante, novo conceito de sombra para reduzir o stress hídrico em cafezais conillon. In: CONGRESSO BRASILEIRO DE PESQUISAS CAFEEIRAS, 24., 1998, Poços de Caldas. *Trabalhos apresentados*... Rio de Janeiro: MAA/SDR/PROCAFÉ/PNFC, 1998, p. 29.

MATSUMOTO, S. N.; VIANA, A. E. S. Arborização de cafezais na região nordeste. In: MATSUMOTO, S. N. (Ed.). *Arborização de Cafezais no Brasil*. Vitória da Conquista, BA: Edições UESB, p. 167-195. 2004.

MONTAGNINI, F. *Sistemas Agroflorestales: Principios y Aplicaciones en los Trópicos*. 2. ed. Organización para Estudios Tropicales, San José, Costa Rica., 1992, 622 p.

MUSCHLER, R. Shade or sun for ecologically sustainable coffee production: a summary of environmental key factors. In: *III Semana Científica del Centro Agronómico Tropical de Investigación y Enseñanza* (CATIE). Turrialba: CATIE, p. 109-112. 1997.

PARTELLI, F. L.; ARAUJO, A. V. ; VIEIRA, H. D. ; DIAS, J. R. M. ; MENEZES, L. F. T.; RAMALHO, J. C. Microclimate and development of 'Conilon' coffee intercropped with rubber trees. *Pesquisa Agropecuária Brasileira*, v. 49, p. 872-881, 2014.

PERFECTO, I.; VANDERMEER, J.; PHILPOTT, S. M. Complex ecological interactions in the coffee agroecosystem. *Annual Review of Ecology, Evolution, and Systematics*, v.45, p.137-158, 2014.

PEZZOPANE, J. R. M.; MARSETTI, M. M. S.; FERRARI, W. R. ; PEZZOPANE, J. E. M. Alterações microclimáticas em cultivo de café conilon arborizado com coqueiro-anão-verde. *Revista Ciência Agronômica*, v. 42, p. 865-871, 2011.

RENA, A. B.; DaMATTA, F. M. O sistema radicular do cafeeiro: estrutura e ecofisiologia. In: ZAMBOLIM, L. (Ed.). *O estado da arte de tecnologias na produção de café*, Viçosa, MG: Universidade Federal de Viçosa, p. 11-92. 2002.

REYNOLDS, J. S. *Soil nitrogen dynamics in relation to groundwater contamination in the Valle Central, Costa Rica*. Tese (Doutorado), University of Michigan, MI, USA, 1991.

RONCHI, C. P.; FERREIRA, J. S. J.; FONSECA, A. F. A. da. Maturação de frutos em clones de café conilon submetidos ou não ao sombreamento com seringueira. In: *V SIMPÓSIO DE PESQUISA DOS CAFÉS DO BRASIL*. Águas de Lindoia. *Anais*... [CD-Rom]. Brasília, DF: Embrapa Café, v. 5, 2007.

SALES, E. F.; ARAUJO, J. B. S. Levantamento de árvores consorciadas com cafeeiros no Estado do Espírito Santo. In: CONGRESSO BRASILEIRO DE AGROECOLOGIA, 3., 2005. Florianópolis, SC. *Anais*... Florianópolis: ABA, 2005. CD-ROOM.

SALES, E. F.; MÉNDEZ, V. E.; CAPORAL, F. R. Sistemas agroflorestais com cafezais no estado do Espírito Santo: o olhar do agricultor. *Cadernos de Agroecologia*, v. 8, n. 2, 2013a.

SALES, E. F.; MÉNDEZ, V. E.; CAPORAL, F. R.; FARIA, J. C. Agroecological transition of conilon coffee (*Coffea canephora*) agroforestry systems in the State of Espírito Santo, Brazil. *Agroecology and Sustainable Food Systems*, v. 37, p. 405-429, 2013b.

SIAG. Sistema de informações agrometeorológicas. *Dados médios da série histórica da estação meteorológica localizada no município de Linhares-ES*. Disponível em: <http://www.incaper.es.gov.br/clima/linhares_sh.htm>. Acesso em: 24 abr. 2006.

SOMARRIBA, E. Timber harvest, damage to crop plants and yield reduction in two Costa Rican coffee plantations with *Cordia alliodora* shade trees. *Agroforestry Systems*, v. 18, p. 69-82, 1992.

SOUZA, G. P.; CANDIDO, A. O.; SOUZA, A. F.; JESUS JUNIOR, W. C. Influência do sombreamento na produção de café cereja para região sul capixaba. In: *XIII ENCONTRO LATINO AMERICANO DE INICIAÇÃO CIENTÍFICA, IX ENCONTRO LATINO AMERICANO DE PÓS-GRADUAÇÃO E III INIC JR DA UNIVERSIDADE VALE DO PARAÍBA*, 2009, São José dos Campos, SP, Ciência e Ética. São José dos Campos, SP: UNIVAP, 2009.

ZAMORA, G.; SOTO, B. Árboles usados como sombra para café y cacao. *Revista Cafetalera*, Guatemala, p. 27-32, oct-nov 1976.

Support

Consórcio Pesquisa Café

FAPES
FUNDAÇÃO DE AMPARO À PESQUISA E INOVAÇÃO DO ESPÍRITO SANTO

GOVERNO DO ESTADO DO ESPÍRITO SANTO
Secretaria de Ciência, Tecnologia, Inovação e Educação Profissional

Realization

Incaper
Instituto Capixaba de Pesquisa, Assistência Técnica e Extensão Rural

GOVERNO DO ESTADO DO ESPÍRITO SANTO
Secretaria da Agricultura, Abastecimento, Aquicultura e Pesca

Rua Afonso Sarlo, 160 - Bento Ferreira - Caixa Postal: 391
CEP: 29052-010 - Vitória, ES - Brasil
Telephone: 55 27 3636 9846 - biblioteca@incaper.es.gov.br
www.incaper.es.gov.br

ISBN 978-85-89274-32-6
9 788589 274326