Chapter 29
Applying the Meta Soil Model: The Complexities of Soil and Water Security in a Permanent Protection Area in Brazil

Marcos B. Ceddia, Sabine Grunwald, Érika F.M. Pinheiro, Katsutoshi Mizuta, Christopher M. Clingensmith, and Milton Marques Fernandes

Abstract Soil security denotes freedom from risks of losing a specific or a group of soil functions. This case study in the permanent protection area of Sana river (PPA-Sana), Brazil, addresses the relationship between soil security and water security. It explores the soil function "the provision of clean water and its storage, as well as filtering the contamination of water ways." The study also presents a formal way to put soil security into practice applying the meta soil model. Meta soil modeling is built on integral theory that facilitates to understand the complexity of soil, water, and other securities. The soil and water securities in the PPA-Sana are interconnected and at risk. Specifically, one of the main problems is the discharge of soil sediments in the rivers as a consequence of soil erosion. Soil erosion and compaction constrain soil and water security, and these were monitored and mapped in order to provide support for policy interventions. However, our findings suggest that producing better soil maps and more monitoring are not enough to improve soil and water security. On the contrary, awareness building, creating trust among stakeholders, and better integration among quadrants of the integral model would lead to an enhancement of soil and water security. In essence, cognizance (the sixth dimension of soil and other securities) is profoundly important to allow integration of human and biophysical system dimensions.

M.B. Ceddia (✉) • É. F.M. Pinheiro
Soil Department, Institute of Agronomy, Universidade Federal Rural do Rio de Janeiro (UFRRJ), Seropédica, RJ, Brazil
e-mail: marcosceddia@gmail.com

S. Grunwald • K. Mizuta • C.M. Clingensmith
Soils & Water Science Department, University of Florida, Gainesville, FL 32611, USA

M.M. Fernandes
Cinobelina Elvas. Campus Cinobelina Elvas UFPI, Universidade Federal do Piauí, Teresina, Brazil

D.J. Field et al. (eds.), *Global Soil Security*, Progress in Soil Science,
DOI 10.1007/978-3-319-43394-3_29

Keywords Integral theory • Cognizance • Soil quality • Water quality and ecosystem service • Meta soil model

29.1 Introduction

The concept of soil security has been developed to protect and sustain the valuable soil resources by reframing the importance of soil in context of solving wicked global environmental issues (Grunwald et al. 2015). The term "security" in common usage denotes freedom from various risks (King and Murray 2001). Applied to soil science, we define soil security "as freedom from risks of losing a specific or a group of soil functions."

Many studies in soil science are focused on soil management and conservation. They focus on characterizing the soil's chemical, physical, biological, and morphological properties; soil classes; quality; nutrient contents; carbon storage; biomass; and others. However, soil is an integral component of environmental, economic, social, political, legal, educational, and other systems that show much complexity. Contemporary soil mapping and assessment that describe or quantify soils are not able to assess the full soil functionality, value, and services that soils provide and, thus, fall short to address soil security. Morris (1995), in his book titled *The Political Economy of Land Degradation*, provides us with good lessons about how politics failed to prevent and recover the soil degradation in dryland regions. According to him, the debate about soil degradation had concentrated on the "scientific" identification of problems and the consequent construction of rational and "scientific" solutions. However, "experts" have persistently failed to identify correctly the institutional dysfunctions causing land degradation. Besides, a central plan (top-down decision system) developed by those experts, did not consider the explicit wants and needs of the local peasants and the complexity of their interactions with the nature and the economic and political systems. A more integral view is needed that allows experts, stakeholders, land tenants, land users, and residents to interact and find common ground to share facts about soils, raise awareness of soil-related issues, and find appropriate solution to enhance or optimize soil functions.

Integral theory weaves together the significant insights from all of the major human disciplines of knowledge, including natural and social sciences as well as arts, philosophy, and humanities. In a certain sense, integral approaches are "meta-paradigms" or ways to draw together an already existing number of separate paradigms into an interrelated network of approaches that are mutually enriching. Because integral theory systematically includes more of reality and interrelates it more thoroughly than any other current approach to assessment and solution building, it has the potential to be more successful in dealing with the complex problems we face in the twenty-first century (Esbjörn-Hargens 2009).

Here, we apply integral theory to address the complexity of soil and water security and to show how it is connected to other securities. It explores the soil function "the provision of clean water and its storage, as well as filtering the contamination of water ways." In fact, this soil function is not the only one in the context of the study site; however, considering the importance of the landscape and waterfall in the economy of the region, it can be elected as the most important. We exemplify our integral approach to soil security with a case study from Brazil where both soil and water securities have been threatened.

29.2 Integral Theory

According to integral theory, there are at least four irreducible perspectives or quadrants (subjective, intersubjective, objective, and interobjective) that must be consulted when attempting to fully understand any issue or aspect of reality (Esbjörn-Hargens 2009). The quadrants express the simple recognition that everything can be viewed from two fundamental distinctions: (1) an interior and exterior perspective and (2) a singular and plural perspective. The four quadrants allow investigating an issue (e.g., soil-water security- Fig. 29.1) from four distinct perspectives: (1) the UL (upper left) quadrant that represents the individual-interior perspective in which individuals voice their subjective experiences based on sense perceptions and meaning they derive; (2) the LL (lower left) quadrant which discloses cultural worldspace in which groups and communities of people come together and express their values, beliefs, and perceptions from a collective vantage point; (3) the UR (upper right) quadrant that captures the individual-exterior perspective which can be objectively described through mapping, monitoring, recording, or other empirical observations; and (4) the LR (lower right) quadrant that reveals system perspectives through system theory of interconnected social, economic, political, environmental, and other systems which represent the collective-exterior point of view (Wilber 2000a, 1997). The integral model allows to put ecological problems under the integral lens providing a holistic view because it combines different perspectives – the "I" (UL quadrant), "We" (LL quadrant), "It" (UR quadrant), and "Its" (LR quadrant) (Wilber 2000a, b). Esbjörn-Hargens and Zimmerman (2009) applied Wilber's integral theory to the ecological and environmental realms which brought forth integral ecology. Weichselgartner and Kasperson (2010) asserted that there is broad agreement that more integrative assessments are needed to address global environmental problems. However, there is no consensus on *what* needs to be integrated and *how* that integration should be accomplished. We assert that integral theory and integral ecology are poised to provide a framework for soil security and interconnected securities, such as water security. The integral framework allows integration of multiple perspectives that are populated by distinctly contrasting methods/approaches. This integrative approach disclose a more comprehensive view of soil and water security than any other specialized study that looks at only the conditions or only the capability of soils a study region. Importantly, integral theory and integral ecology aim to integrate our knowledge and understanding within and across all four quadrants. Therefore, the integral approach goes beyond conventional soil and water applications. The quadrants applied in this study contextualizing the soil and water security are shown in Fig. 29.1.

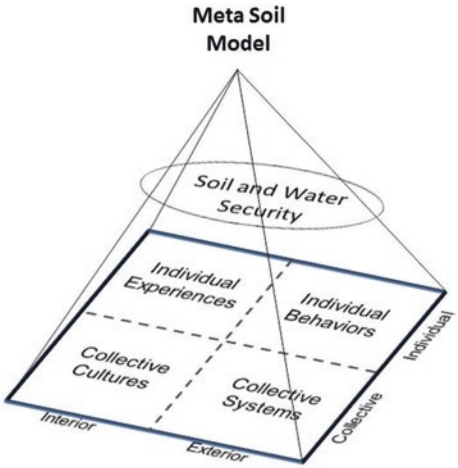

Fig. 29.1 The four quadrants of the integral map derived from integral theory that provides all perspectives to view soil and water security

29.3 Materials and Methods

29.3.1 The Study Site

The study site is an ecotourism area called “permanent protection area of Sana river” (PPA-Sana) which is located in the municipality of Macaé, Rio de Janeiro State, Brazil (Fig. 29.2). In the past, the region was covered by a dense rainforest (Atlantic Forest), and according to the Köppen climate classification, the region falls within the “mild temperature with dry and warm summer” (Cwb) class. The PPA-Sana covers an area of 11,802 ha (Sana watershed, Fig. 29.2), and the Sana river has an extension of 20 km. The study focused on the stretch of the river between Arraial do Sana and Barra do Sana region, which is the most populated area prominently visited by tourists. The selected stretch of the river (~30 % of the Sana river) encompasses a territory of 360 ha, which represents the land surrounding the Sana river and its respective tributaries. According to the soil survey report (Macaé 2004a), the main soil types in the region are inceptisols (77 %), ultisols (18 %), and entisols (5 %).

29.3.2 Problem Identification

According to monitoring and observations in the Gloria and Palmital watersheds, soil and water bodies were identified as impaired (Ceddia et al. 2012). The water quality for drinking water usage for the two watersheds (Gloria and Palmital) is shown in Fig. 29.3. The water turbidity in the outlet of each watershed was monitored to estimate the sediments delivered due to soil erosion. These measurements were used to calculate the annual cost of soil erosion based on the cost of water treatment.

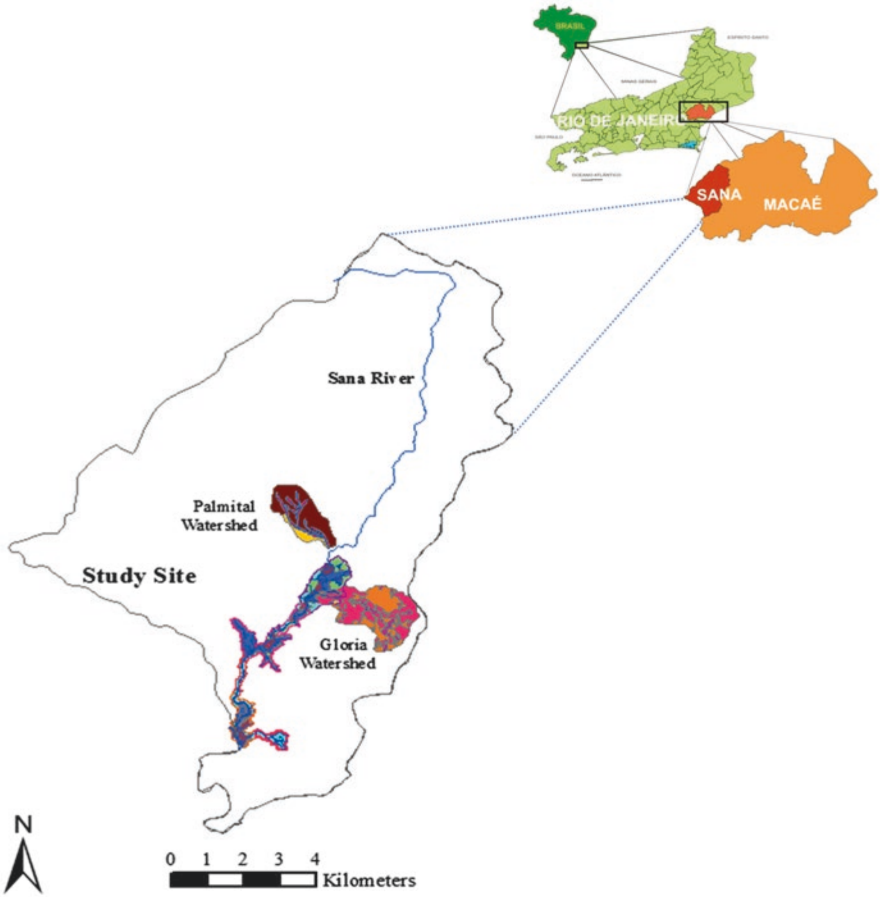

Fig. 29.2 Location of the study site, highlighting the Sana river and the watersheds

The soil quality was assessed by the soil quality index (SQI) which was computed based on the measurements of the following soil attributes: bulk density, macroporosity, water infiltration, penetration resistance, soil organic carbon, and phosphorus. The SQI was calculated considering the forest, pasture, and agriculture use, according to Eq. 29.1.

$$SQI = \sum_{n}^{i=1} Si \times wi \tag{29.1}$$

where *SQI* – soil quality index, a number that varies from 0 to 100; *Si* – is the score of the *i*-th input attribute, a number between 0 and 100; *n* – number of soil attributes; and *wi* – weight corresponding to the *i*-th parameter, a number between 0 and 1.

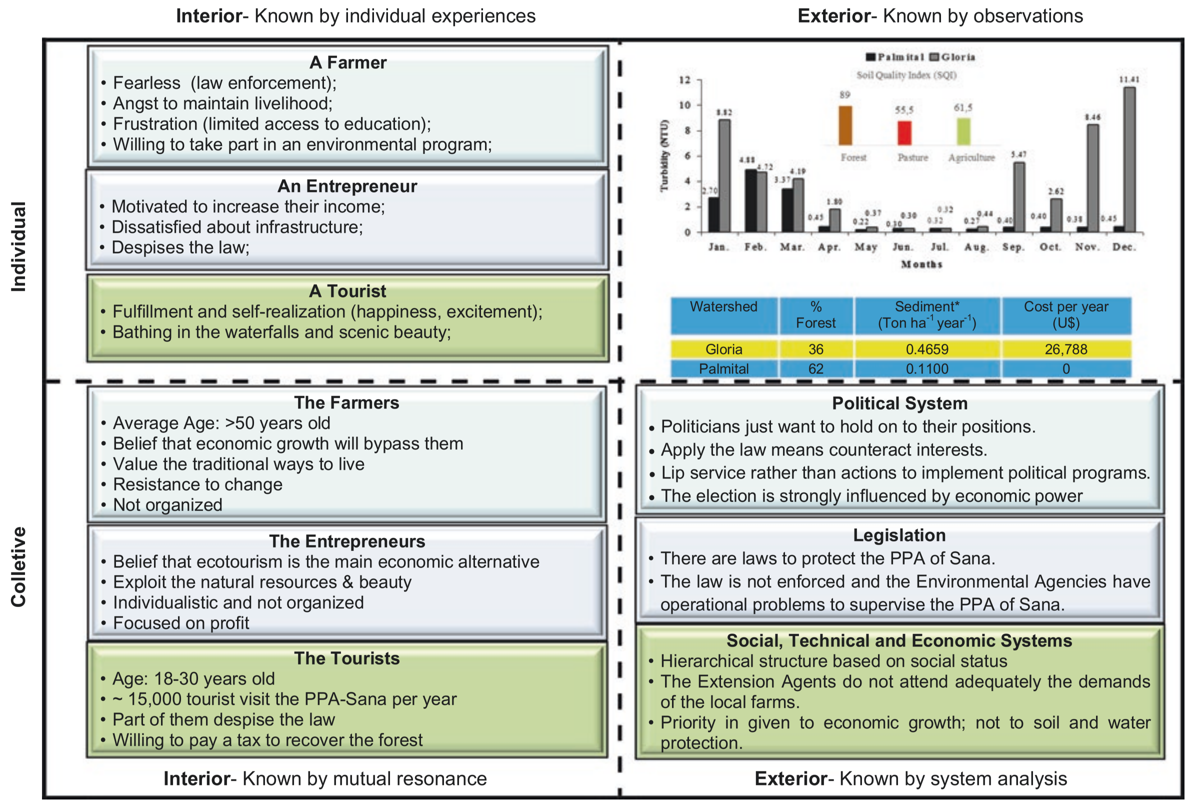

Fig. 29.3 The integral theory analysis and the meta soil model applied to the study site

29.3.3 The Economic and Social Aspects

The social and economic data of the region were surveyed by different interviews with local residents, 73 farmers, 30 entrepreneurs, and 1,081tourists, encompassing a sample of 1184 people (Fernandes 2009; Macaé 2004b). The interviews surveyed information about education and income level, water supply and sanitation, social organizations, their demands and perceptions about environmental issues, public services, and political system.

29.4 Results and Discussion

The environmental and socioeconomic data were allocated to the four quadrants of the integral map (Fig. 29.3). In the UR quadrant, the soil and water quality indices, as well as the environmental cost due to soil erosion, are shown. The Glória watershed, with less forest coverage, showed lower soil quality and a higher level of turbidity at the outlet. The discharge of soil sediments into the river implied an extra cost of US $26,788 per year for water treatment (Ceddia et al. 2012). The soil and water securities have been at risk, and the question is how to shift the procedures applied along the PPA-Sana to reverse this degradation process.

Considering the main results illustrated in the other three quadrants (Fig. 29.3), we highlight that the community has had many demands not attended by the government. And consequently, the local residents, farmers, entrepreneurs, and tourists do not trust in the political systems and public agencies. On the other hand, the environmental agencies do not trust farmers and entrepreneurs to carefully use and manage soil and water in a way that does not adversely affect the watershed. Clearly, the dissatisfaction and the mutual distrust of locals and tourists in relation to the government are a key factor that constrains soil and water security. This situation hinders the implementation of necessary changes to secure soil and water resources and enables their functioning for the greater good of the whole community. Thus, the solution to achieve soil and water security necessarily involves confronting social and political problems, which is not usually done by experts in soil and water management that focus on soil mapping and monitoring of water quality. In fact, the solution requires a broader approach integrating the various dimensions of the problem. In this context, we present the concept of *cognizance* (Clingensmith et al. 2015), a new dimension of soil security, contextualized for the case study (Fig. 29.4). Cognizance allows recognizing chasms and disconnects between and within quadrants of the integral map. For example, right (UR and LR quadrants) and left (UL and LL quadrants) are disconnected somewhat in the two watersheds constraining to secure soils and water. This suggests that a better soil map or more monitoring will not help to improve soil and water security. On the contrary, awareness building, creating trust among stakeholders, and better integration among quadrants would lead to an enhancement of soil and water security. In essence, cognizance is

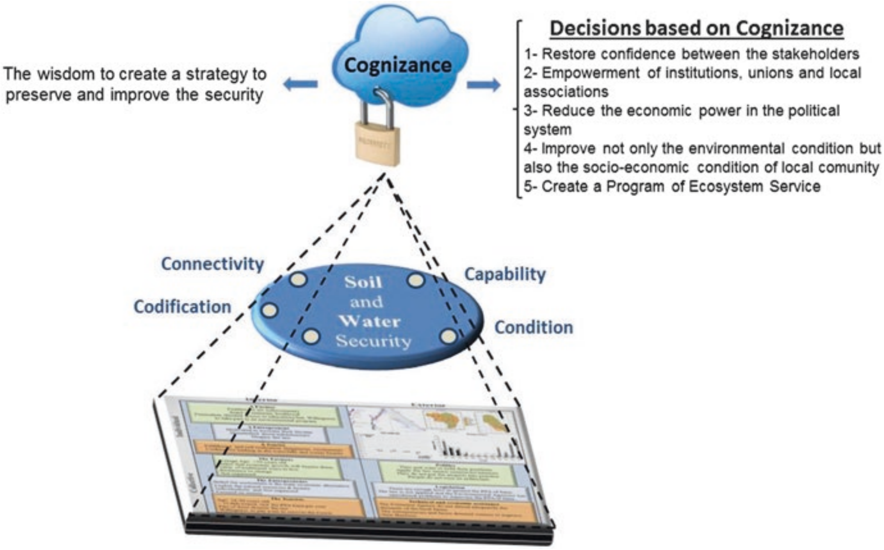

Fig. 29.4 Cognizance, the integration of the knowledge to enhance the soil and water security

profoundly important to allow integration of human and biophysical system dimensions. Cognizance also allows creating a strategy to preserve and improve soil and water security considering the complexity of the human-environmental interactions. Basically, there are at least five points to be carefully addressed: (1) restore confidence between the stakeholders; (2) empowerment of institutions, unions, and local associations; (3) reduce the economic power in the political system; (4) improve not only the environmental condition but also the socioeconomic condition of local community; and (5) create a program of ecosystem service. Essential to achieve soil and water security is the rescue of the respect and confidence of the locals in political and public institutions. The rehabilitation becomes possible when the actions not only prioritize the legal repression but also the presentation (by the political system) of solutions that respect the history, knowledge, beliefs, and aspirations of the local community. The institutions, both for the oversight and to support the farmers, entrepreneurs, and tourists, should be fortified. Fortify implies the improvement of the infrastructure, the wages of the staff, and the methods of action. A key and controversial point concerns the electoral process. The strong influence of private funding during the elections (companies and entrepreneurs) causes a sensitive bias in the results. Thus, commonly, municipality mayors and councilors of Macaé are more committed to the interests of campaign contributors than to the aspirations of most citizens. This is one of the reasons why politicians hardly put into action what they promised.

Some experiences in Brazil (São Paulo 2012) have shown that the application of payment for environmental services programs gains interest among farmers in preserving the soil and the water. Through these programs, the land owners become not only agricultural producers but also providers of environmental services. Applying this program at the study site, the farmers could receive state financial compensation for maintaining the security of soil and water.

29.5 Conclusions

The soil and water securities are connected and at risk in the PPA-Sana. Specifically, one of the main problems of the water security is the discharge of soil sediments in the rivers as a consequence of soil erosion. The discharge of soil sediments into the river implied an extra cost of US $26,788 per year for water treatment. The integral theory enhances our capacity to understand the system complexity through inclusion of multiple distinct perspectives. Our findings suggest that not a better soil map or more monitoring helps to improve soil and water security. On the contrary, awareness building, creating trust among stakeholders, and better integration among quadrants would lead to an enhancement of soil and water security. In essence, cognizance (the sixth dimension of soil and other securities) is profoundly important to allow integration of human and biophysical system dimensions.

Acknowledgments The authors acknowledge Conselho Nacional de Desenvolvimento Cientifico e Tecnológico (CNPq: 249594/2013-7) and Coordenação de Aperfeiçoamento de Pessoal de Nivel Superior (CAPES: 1574-14-0) for the postdoctoral scholarship granted to Drs. Ceddia and Pinheiro.

References

Ceddia MB, Milton MF, May PH, Anjos LHC (2012) Payments for hydrological environmental services in the Atlantic Forest. In: Bilibio C, Hensel O, Selbach J (eds) Sustainable water management in the tropics and subtropics – case studies in Brazil. Unikassel, Universidade Federal do Pampa, pp 1223–1249. Kassel (Germany)

Clingensmith CM, Gavilan C, Grunwald S, Mizuta K, Pinheiro EF, Ross CW, Wang C (2015) The sixth dimension of soil security: ideas from integral ecology. In: The sixth dimension of soil security: ideas from integral ecology. Soil Science Society of America, College Station

Esbjörn-Hargens S (2009) An overview of integral theory. Integral Institute. Resource Paper No. 1, March 2009, pp 1–24. Integral Life

Esbjörn-Hargens S, Zimmerman ME (2009) Integral ecology: uniting multiple perspectives on the natural world. Integral Books Publishers, Boston

Fernandes M (2009) Valoração dos serviços ambientais da floresta de Mata Atlantica associados a qualidade e quantidade da agua na APA do SANA. Dissertation, Unversidade Federal Rural do Rio de Janeiro, Rio de Janeiro

Grunwald S, Vasques GM, Rivero RG (2015) Fusion of soil and remote sensing data to model soil properties. Adv Agron 131:1–109

King H, Murray C (2001) Rethinking human security. Polit Sci Q 116:585–610

Macaé (2004a) Relatorio Detalhado dos solos da APA do Rio Sana-Macae-RJ, Rio de Janeiro

Macaé (2004b) Plano de Manejo da APA do Sana. Prefeitura de Mace, Macae

Morris J (1995) The political economy of land degradation-pressure groups, foreign aid and the myth of man-made deserts. The Institute of Economic Affairs, Westmister/London
São Paulo (2012) Experiencias de Pagamento por serviços ambientais no Brasil. Secretaria do Meio Ambiente/Coordenadoria de Biodiversidade e Recursos naturais, Sao Paulo
Weichselgartner J, Kasperson R (2010) Barriers in the science-policy-practice interface: toward a knowledge-action-system in global environmental change research. Glob Environ Chang 20:266–277
Wilber K (1997) The integral vision: the good, the true, and the beautiful. In: The eye of the spirit: an integral vision for a world gone slightly mad. Shambhala Publication, Boston, pp 1–36
Wilber K (2000a) A brief history of everything. Shambhala Publication, Boston
Wilber K (2000b) Sex, ecology, spirituality – the spirit of evolution. Shambhala Publication, Boston