UNIVERSIDADE ESTADUAL DE CAMPINAS
INSTITUTO DE FILOSOFIA E CIÊNCIAS HUMANAS

RAMON FELIPE BICUDO DA SILVA

EUCALIPTO E MATA ATLÂNTICA: ANÁLISE DO USO E COBERTURA DA TERRA E SUAS CONEXÕES BIOFÍSICAS, POLÍTICAS E SOCIOECONÔMICAS

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RAMON FELIPE BICUDO DA SILVA

Eucalipto e Mata Atlântica: análise do uso e cobertura da terra e suas conexões biofísicas, políticas e socioeconômicas

Tese apresentada ao Instituto de Filosofia e Ciências Humanas da Universidade Estadual de Campinas como parte dos requisitos exigidos para a obtenção do título de Doutor em Ambiente e Sociedade, na Área Aspectos Biológicos de Sustentabilidade e Conservação.

Supervisor/Orientador: Prof. Dr. Mateus Batistella

Co-supervisor/Coorientador: Prof. Dr. Emilio Federico Moran

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Profa. Dra. Simone Aparecida Vieira

Prof. Dr. Roberto Luiz do Carmo

Prof. Dr. Diogenes Salas Alves

Prof. Dr. Jean Pierre Henry Balbaud Ometto

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“Maravilhados com a capacidade da natureza para se regenerar, fomos ficando cada vez mais ansiosos com o destino de todo o nosso planeta. Compreendemos o absurdo da idéia de que a natureza e a humanidade podem de algum modo ser separadas.”

(Sebastião Salgado, 2013. Gênesis)

Fotografia tirada durante trabalho de campo, ano de 2012. A imagem destaca a paisagem de “mares de morros”, observada no município de Cunha. Os pontos brancos observados sobre as pastagens representam o gado. No fundo de vale, em primeiro plano na imagem, pode-se observar um pequeno fragmento de vegetação nativa.

Depois que deixarmos de habitar esta terra, ainda ficarão por anos as cicatrizes deixadas por nossa civilização, sobre sua face e entranhas. Não obstante, depois de algum tempo, esta terra estará renovada, viva e vicejante. Sem estarmos aqui para admirar este incrível processo de auto-cura, nos resta o privilégio de contemplar a maravilha que é o poder da natureza, aqui e agora. A floresta está reclamando seu quinhão de terra.

(Ramon Felipe Bicudo da Silva)

Fotografia tirada durante trabalho de campo, ano de 2014 – Paraibuna/SP.

Estas mãos calejadas e marcadas pelos anos da lida no campo, sobre tudo no trato da pecuária leiteira Valeparaibana, são marcas de um passado rústico, outrora vivido nas zonas rurais brasileiras. Achá-las se tornou uma raridade, nem tanto para o Vale do Paraíba. Elas representam mais que o passado ou as duras marcas de um trabalhador rural; representam de forma contundente o modo de vida mediado pelas relações de trabalho no campo, antecedentes à modernização da agricultura brasileira.

(Ramon Felipe Bicudo da Silva)

Resumo

O Vale do Paraíba Paulista é uma região de importância econômica para o Estado de São Paulo. Com população superior a dois milhões de habitantes, concentrada em áreas urbanas (95%), sobretudo nos municípios do eixo rodoviário Presidente Dutra, foi elevada à categoria de Região Metropolitana em 2012. Eixo conector entre São Paulo e Rio de Janeiro, foi uma das primeiras regiões brasileiras a enfrentar profundas mudanças em suas paisagens, resultado dos séculos de colonização. Representante do bioma Mata Atlântica, a região apresentava, em 1962, aproximadamente 225 mil hectares de vegetação florestal nativa, cerca de 16% de sua extensão territorial. Mudanças profundas na economia brasileira, especialmente após os anos 1950, com o Plano Nacional de Metas, o processo de descentralização da indústria em São Paulo e com o projeto nacional de modernização da agricultura, iniciado na década de 1960, trouxeram para a região novos determinantes para as trajetórias futuras do uso e cobertura da terra. O objetivo desta pesquisa foi entender as conexões socioeconômicas e biofísicas do Vale do Paraíba Paulista com o processo de transição florestal. A metodologia para desenvolver a pesquisa incluiu o mapeamento do uso e cobertura da terra (anos de 1985, 1995, 2005 e 2011) por meio de imagens *Landsat-5 Thematic Mapper*, modelos de análise de mudanças por regressão logística e redes neurais, entrevistas estruturadas e semiestruturadas com *stakeholders* e aplicação de questionários em noventa propriedades rurais. Foi observado que a cobertura florestal em 2011 alcançou aproximadamente 446 mil hectares, crescimento de 98% em relação a 1962. Esse processo ocorreu majoritariamente sobre áreas de pastagens degradadas (74%) e nas regiões com declividades superiores a 20%. Essa pesquisa indica um processo de transição florestal decorrente do mercado internacional de commodities (polpa de celulose de eucalipto), das políticas públicas para conservação, da diminuição das atividades agropecuárias, do desenvolvimento econômico industrial na região, da participação da sociedade no controle do desmatamento e do estado de escassez florestal no bioma Mata Atlântica.

Palavras Chave: Transição florestal; Mata Atlântica; Uso da terra; Sensoriamento Remoto.

Abstract

The Paraíba Valley is a region of economic importance to the state of São Paulo. With a population of more than two million inhabitants concentrated in urban areas (95%), especially in the municipalities located along the Presidente Dutra highway, it was elevated to a metropolitan region in 2012. Connecting São Paulo and Rio de Janeiro, the Paraíba Valley was one of the first Brazilian regions that faced profound changes in its landscapes, as a result of centuries of colonization. Within the Atlantic Forest biome, the region had about 225 thousand hectares of native forest in 1962, about 16% of its territorial extension. Profound changes in the Brazilian economy, especially after the 1950s, with the National Target Plan, the industry's decentralization process in São Paulo and the national project of agricultural modernization (since the 1960s), brought to the Paraíba Valley a new context, determinant to future land use and land cover trajectories. The objective of this research was to understand the socioeconomic and biophysical connections of the Paraíba Valley with the forest transition process. The research methodology included the mapping of land use and land cover (years 1985, 1995, 2005 and 2011) on Landsat-5 Thematic Mapper imagery, model analysis of change using logistic regression and neural networks, structured and semi-structured interviews with stakeholders, and household survey in ninety farms. We observed that the forest cover in 2011 reached approximately 446 thousand hectares, a net gain of 98% since 1962. This process occurred mostly on degraded pastures (74%) and in areas with slopes greater than 20%. This research indicates a Forest Transition process influenced by the international commodity market (eucalyptus pulp), public policies for conservation, the decrease of agricultural activities, industrial economic development in the region, the society's engagement in controlling deforestation, and the situation of forest scarcity in the Atlantic Forest biome.

Keywords: Forest transition; Atlantic Forest; Land Use; Remote Sensing.

Prefácio

Ao escrever o presente trabalho, senti necessidade de esclarecer o leitor a respeito da pessoa que indelevelmente inspirou esta pesquisa, bem como as veredas vivenciais didático-pedagógicos que conduziram a este desfecho. Não há mais dúvidas que sejam muitos os caminhos e que são muitas as pedras. Sem fazer apologia às engenharias, sabemos que as pedras podem ser removidas, ou pelo menos roladas. Sendo assim, descobrir os caminhos desta pesquisa, o nobre caminhar sobre a interdisciplinaridade e a superação pessoal em diversas disciplinas do conhecimento, significou lidar com muitas pedras. Agora, posso dizer que sinto felicidade pelo compromisso assumido em um programa interdisciplinar de pós-graduação, e por saber que ainda haverá muitas outras "pedras no caminho", desafios necessários à manutenção de uma mente saudável, perspicaz e ao desenvolvimento humano e profissional.

Cresci em um bairro simples, em uma casa simples. Logo cedo, com meu pai e avô, tive a felicidade de desfrutar a vida rural, tocando o gado, ordenhando e bebendo leite direto da "teta" da vaca, andando a cavalo, pescando e aprendendo sobre os costumes caipiras dos sertões paulistas. Com minha mãe, tive a chance de crescer em meio a um importante departamento de pesquisa e aconselhamento genético, lugar que me aproximou da biologia e da ciência, logo na infância.

Em minha terra natal, Botucatu, cidade de tamanho mediano e assentada sobre o reverso de uma Cuesta Basáltica, tive a infância e adolescência banhadas pelas águas das inúmeras cachoeiras que ali descem a "serra", criando um emaranhado de microambientes entre o Cerrado e a Mata Atlântica. Pude logo cedo perceber a beleza e a importância do ambiente para a nossa vida e para os meios produtivos que sustentam nossa sociedade moderna, alicerçada sobre relações capitalistas e na exploração dos recursos naturais.

Foi assim, que em 2001, comecei o curso de biologia. Logo no primeiro ano, estagiei em um departamento de botânica, onde dei meus primeiros passos na pesquisa e na ciência da identificação das plantas. Aprendi que para conhecê-las não bastava decifrar suas estruturas, seguindo guias e chaves de identificação. Era preciso também compreender seu comportamento ecológico, sua fase de flora e frutificação, suas limitações climáticas, condições edáficas, enfim, sua vida. Como estagiário em um projeto de extensão universitária entre 2002 a 2005, na área de educação ambiental, tive a oportunidade de despertar o senso crítico, necessário a uma postura cidadã ativa, frente aos temas urgentes que permeiam as questões ambientais e humanitárias.

Como estudante de biologia, encarei o desafio de desenvolver minha pesquisa de conclusão de curso na Amazônia. Ali, com o uso da pesquisa social e do conhecimento biológico do ecossistema Amazônico, tive minha primeira imersão em uma pesquisa interdisciplinar. Vale lembrar que neste período (ano de 2005) tive o primeiro contato com a obra do prof. Emilio F. Moran. Desde então, minha admiração por seu trabalho cresceu, assim como o interesse por pesquisas interdisciplinares focando as relações entre os seres humanos e o ambiente. Apaixonado por mapas desde tenra idade, trabalhei na Prefeitura Municipal de Botucatu depois de formado, quando tive o primeiro contato com a cartografia. Naquele momento decidi que deveria retornar à academia, e foi na Universidade Estadual Paulista, campus de Botucatu, que encontrei esta oportunidade. Durante o mestrado na área de Ciências Agronômicas, dei passos importantes nas áreas de geoprocessamento, ciências dos solos e recursos hídricos. Antes de finalizar meu mestrado, durante minhas pesquisas a artigos científicos, fui conduzido ao campo interdisciplinar das interferências humanas nas mudanças ambientais, através das pesquisas nas ciências sociais e geoespaciais, com foco nas transformações do uso e cobertura da terra. Mais uma vez, deparei-me com a douta cátedra de Emilio F. Moran . Desta vez, não foi apenas ele, mas também o pesquisador da Embrapa e professor do programa Interdisciplinar de Doutorado em Ambiente e Sociedade da Universidade Estadual de Campinas, Doutor Mateus Bastitella . Imediatamente decidi que aquele programa de pós-graduação seria a minha opção para o doutorado.

Como não poderia ser diferente, em meu encontro pessoal e profissional com este pesquisador, fui conduzido à ciência geoespacial, filosofia e às teorias sobre as mudanças no uso e cobertura da terra, transição florestal e mudanças ambientais. Desse modo, esboçamos naturalmente uma pesquisa interdisciplinar, com foco na ciência geoespacial e nas dimensões humanas das mudanças no uso e cobertura da terra. A decisão pelo Vale do Paraíba paulista e a questão da eucaliptocultura e Mata Atlântica, ainda era um tema do qual estava me aproximando e foi definido após inúmeras conversas com pesquisadores do NEPAM e de outros centros, entre eles a EMBRAPA Monitoramento por Satélite. Feliz decisão.

Para concluir este preâmbulo, foi ainda no início do segundo ano de doutorado que conheci pessoalmente o Professor Doutor Emilio F. Moran, que se tornou meu co-orientador, contribuindo com o trabalho de meu orientador, Professor Doutor Mateus Batistella. *Touché*!

Pensando além do dossel

Se apontarmos a seta do tempo para o passado, saberemos que no Vale do Rift, em território etíope, foi o epicentro da jornada humana há mais de 60 mil anos. Durante esta longa odisseia, o homem não apenas colonizou o mundo, em todas as paisagens que alcançou, mas também o modificou. Hoje, a face da terra não é mais a imaculada natureza intocada. Poucos são os rincões deste planeta onde não estivemos e mesmo assim, estes bastiões de natureza indômita que ainda restam, são constantemente valorados por suas riquezas, presentes em seus bosques, águas, solos e subsolos. O imperativo do desenvolvimento econômico justificou e ainda justifica todas as medidas necessárias para a manutenção do sistema financeiro, político e de produção de bens de consumo.

Ainda em princípios do terceiro milênio, o homem já esteve seis vezes na Lua, está presente com veículos não tripulados há quase uma década na superfície marciana e agora, mais recentemente, os chineses pousaram, com um veículo controlado remotamente na superfície lunar. Já encontra-se no horizonte de agências como a NASA, os investimentos e estudos para as primeiras missões tripuladas a planetas próximos, dentro de nosso Sistema Solar. A sonda espacial Voyager I, em 2013, tornou-se o primeiro objeto construído por humanos a se mover para fora da influência do Sol e entrar para o espaço interestelar, há mais de dezenove bilhões de quilômetros da Terra. Será que eles encontrarão nossas mensagens?

Regressando à Terra, mas ainda observando-a do espaço, vemos um sem número de paisagens, cores, formas e pixels. A revolução tecnológica vivida nas ultimas décadas não pode ser vista apenas como um tipo de vilã da catástrofe ambiental e social do presente momento. É esta mesma revolução que nos deu ferramentas e condições factíveis para monitorar, estudar e compreender o planeta, as mudanças sofridas pelo ambiente e suas consequências sobre a qualidade de vida humana nos mais diversos aspectos: da segurança hídrica à conservação da biodiversidade.

As florestas cobrem cerca de 30% da superfície terrestre, uma porção modesta se comparada às inúmeras regiões áridas e semiáridas encontradas no planeta. De qualquer forma, as florestas concentram grande parte da biodiversidade, rivalizando sua importância apenas com os oceanos, os quais pouco conhecemos. O que sabemos da biodiversidade, ainda hoje, é pouco, pois em um mundo vasto, incontáveis são as formas de vida, as espécies, as formações geológicas e as mais diversas interações ecológicas. Porém, em um mundo regido por leis economicistas, as taxas de perda da biodiversidade superam as taxas de novas descobertas sobre a mesma. As consequências deste modelo de desenvolvimento ainda pouco compreendemos, mas dia a dia, ano após ano, notamos mudanças claras na disponibilidade hídrica, na perda de fertilidade dos solos, nas temperaturas recordes, com verões extremamente quentes e invernos mortalmente congelantes. Não é preciso ser cientista para perceber tais mudanças, basta estar vivo.

No entanto, compreendê-las, trata-se de um grande desafio. São inúmeros os cientistas, os programas de pesquisa e consideravelmente grandes as quantidades de recursos humanos, financeiros e tecnológicos empregados nesta tarefa. Desde o início dos anos de 1980, com o lançamento de programas de estudos climáticos pela Organização Mundial Meteorológica, até o programa Future Earth, lançado em 2012, já se passaram décadas de estudos e progressos no campo das ciências ambientais, sociais e especialmente no elo interdisciplinar que as tornam partes indivisíveis de uma mesma moeda.

O Antropoceno, período marcado pelo protagonismo dos seres humanos sobre as transformações vivenciadas pelo ambiente terrestre, e iniciado após a Grande Aceleração[1], é um termo adequado para moldar o conceito de uma era onde as forças geológicas, atmosféricas e climáticas deixaram de ser as únicas capazes de moldar a superfície e as dinâmicas do planeta. Vivemos em uma interconectada sociedade global. Variadas forças, como o crescimento populacional, conectividade digital, consumo exacerbado e uma gritante desigualdade social, combinados com o declínio dos ecossistemas, com as mudanças climáticas e com a crescente escassez de recursos, criam impactos de longo alcance e muitas vezes imprevisíveis sobre o mundo em que vivemos e onde realizamos nossos negócios.

As florestas desempenham papel fundamental sobre este emaranhado de forças globais. Elas proveem recursos para a sobrevivência humana e de outras espécies, além de recursos para o desenvolvimento econômico. As florestas suprem o mundo com tangíveis e rentáveis recursos, a exemplo da madeira e produtos secundários, como as frutas e fármacos. Não menos importante, elas fornecem empregos e meios de subsistência para inúmeras comunidades, especialmente em

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[1] Santos, F. D. Os Desafios Ambientais Criados pela Grande Aceleração do Pós-Guerra. Nação e Defesa, n^{0}122, p. 61-78, 2009.

regiões com economias emergentes, oferecendo meios para se atingir independência e segurança econômica. Ainda estamos no começo do processo de entendimento e compreensão do valor extraordinário que os ecossistemas florestais têm sobre o planeta. Através de recursos tangíveis, florestas saudáveis e conservadas desempenham importantes serviços ecossistêmicos, como a estabilização de solos e dos nutrientes presentes neles, conservação e purificação da água e habitat para inúmeras espécies animais. Há uma crescente consciência sobre o papel significativo das florestas sobre o ciclo de carbono global e no seu potencial para a mitigação das mudanças climáticas, sendo desta forma, uma excitante e promissora área para a ciência e para a política.

Por estes motivos e considerando a escassez da cobertura florestal de Mata Atlântica na extensão de seu bioma (1.290.692,46 km^2 ou 13% do território brasileiro[2]), as pesquisas com anseio de compreender este ecossistema e os diversos ecossistemas florestais, suas dinâmicas naturais e especialmente suas dinâmicas interações com as sociedades humanas, em um período de notórias mudanças ambientais, climáticas, socioeconômicas e políticas, figuram entre os temas mais prementes para a ciência neste inicio de século 21.

Não é só das florestas que estamos falando. É preciso pensar além do dossel!

[2] Instituto Brasileiro de Geografia e Estatística (IBGE) – Brasil em Síntese http://brasilemsintese.ibge.gov.br/territorio.

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Introdução

Apresentação da tese

O documento de tese apresenta os resultados e o desenvolvimento teórico-metodológico da pesquisa de doutorado conduzida por Ramon Felipe Bicudo da Silva, sob orientação do Professor Doutor Mateus Batistella e co-orientação pelo Professor Doutor Emilio F. Moran. Como poderá ser observado nos capítulos deste documento, o cerne do estudo, bem como a preocupação dos pesquisadores responsáveis por esta pesquisa, centrou-se na questão das dinâmicas do uso e cobertura da terra e especialmente suas implicações para a cobertura florestal de Mata Atlântica, em processo de recuperação no Vale do Paraíba Paulista.

Considerada uma pesquisa interdisciplinar, o uso das geotecnologias, especialmente o sensoriamento remoto, representou ferramenta indispensável para a geração das informações essenciais ao desenvolvimento desta pesquisa: os dados temporais de distribuição espacial do uso e cobertura da terra no Vale do Paraíba paulista entre 1985 e 2011. Esta pesquisa também escutou 107 pessoas, através de enquetes de campo, realizadas entre 2012 e 2014. Em uma primeira fase de pesquisa social, foram realizadas 17 entrevistas com stakeholders que atuam profissionalmente na região de estudo. Em uma segunda fase 90 propriedades rurais foram visitadas e houve a aplicação de um questionário estruturado. Desta forma, a tese de doutorado foi organizada por uma seção de introdução, quatro capítulos e uma conclusão. A seção de introdução procura apresentar o tema, alguns conceitos centrais para a pesquisa, bem como objetivos e hipóteses. Os capítulos de I a IV são apresentados em inglês e no formato de artigos científicos. O capítulo I se concentra no processamento digital de imagens, onde uma técnica multiestágio, que consiste do Índice Melhorado da Diferença Normalizada para Áreas Construídas e da Máxima Verossimilhança, foi a abordagem metodológica adotada para o mapeamento da série temporal de imagens, nos anos de 1985, 1994, 1995, 2005 e 2011, do satélite Landsat-5 Thematic Mapper (TM). Os resultados deste capítulo foram fundamentais para a análise espaço-temporal das mudanças no uso e cobertura da terra e suas conexões com o processo de recuperação da cobertura florestal de Mata Atlântica. Para o estudo das forças condicionantes que estão por trás das mudanças observadas entre os anos mapeados da série temporal, no capítulo II transformou-se uma série de dados sociais, econômicos e demográficos organizados por tabelas, em mapas. Estes mapas junto a outros com informações biofísicas da paisagem (solos, declividade, orientação de vertentes) e mapas de distribuição do uso e cobertura da terra foram integrados em modelos de mudança de Regressão Logística e de Percepção Multicamada por Redes Neurais. Este capítulo trouxe importantes *insigths* sobre a influência de variáveis da paisagem biofísica e socioeconômica, sobre o processo de recuperação da vegetação Atlântica, que reforçaram algumas hipóteses sustentadas pela Teoria da Transição Florestal. Para o capítulo III, dezessete entrevistas foram conduzidas com representantes de instituições públicas e do terceiro setor, com atuação em temas sobre o uso da terra ou conservação e gestão dos recursos naturais. As entrevistas foram organizadas em questionários estruturados e semi-estruturados, e suas informações foram cruzadas com informações secundárias (sociais, econômicas e demográficas), biofísicas e também o uso e cobertura da terra, com finalidade de compreender como o processo de controle do desmatamento, intensificação/tecnificação agropecuária, mercado internacional de commodities (polpa de celulose), mercado de trabalho, industrialização/urbanização e a participação da sociedade no cumprimento da legislação ambiental brasileira, podem estar interconectados com as taxas positivas de crescimento da vegetação florestal no Vale do Paraíba Paulista. Na escala da propriedade rural, o capítulo IV selecionou três municípios valeparaibanos (Bananal, Paraibuna e Taubaté), de acordo com os critérios de desenvolvimento econômico, produção de eucalipto e taxa de cobertura florestal, para aplicação de questionários fechados. Foram aplicados 30 questionários para cada um dos três municípios selecionados. Esta pesquisa de campo foi conduzida com a aplicação de entrevistas com produtores rurais ou moradores da zona rural que fazem uso direto da propriedade para geração de renda ou como uso recreativo, lazer ou turismo. Neste capítulo, foram determinadas as principais motivações que têm contextualizado a tomada de decisão em nível de propriedade rural, com consequências para o controle do desmatamento e para a recuperação da cobertura florestal. A seção de conclusão apresenta um resumo geral da pesquisa, as principais contribuições do trabalho e seus resultados.

Esta pesquisa teve o suporte da Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), processo n^0 2011/13568-0, e entre os meses de setembro de 2013 a abril de 2014, o doutorando desenvolveu estágio de pesquisa internacional no Center for Global Change and Earth Observations, na Michigan State University,

Estados Unidos, apoiado pela agência FAPESP, através do programa internacional de mobilidade, Bolsa de Estágio de Pesquisa no Exterior (BEPE), processo n^{0} 2013/09243-3.

Algumas abordagens teóricas relevantes

Algumas abordagens sobre os processos de uso e cobertura da terra avaliam a dinâmica agropecuária como não sendo apenas um fenômeno ligado à questão da densidade populacional (Boserup, 1965), mas também, a fatores de mercado, levando ao entendimento de que a produção não pode ser explicada apenas em função de interesses locais, já que a influência dos interesses de mercado transcendem as limitações geográficas (Pender, 1998; Browder, 1992; Kates *et al*., 1993); da mesma forma que o crescimento demográfico não deve ser, necessariamente, o responsável pela perda da cobertura florestal em condições locais (Moran e Ostrom, 2005).

Isso sugere que os processos de mudança na cobertura da terra são complexos e construídos por uma relação entre diferentes fatores que criam o contexto no qual os atores tomam suas decisões (Vanwey *et al*., 2009). Sobre este ponto, há uma grande importância em não tratar os indivíduos como atores apenas economicamente racionais, que procuram maximizar seus ganhos pessoais ao custo de qualquer outro resultado potencialmente desejável (Moran, 2011).

Para o caso do Estado de São Paulo, os principais fatores geradores de pressão sobre as florestas remanescentes, são, na atualidade, a atividade agrossilvipastoril e a expansão urbana (Ipardes, 2007). Os desflorestamentos são provocados por causas regionais, entre as quais os fatores econômicos, institucionais e políticos que parecem impulsionar a expansão agrícola, a exploração da madeira e o desenvolvimento da infraestrutura (Moran, 2011). O Vale do Paraíba Paulista, inserido no bioma Mata Atlântica, teve elevados índices de degradação desde o primeiro ciclo agrário de sua história, a cafeicultura (primeira metade do século 19) (Zunquin, 2007). No decorrer deste século e do seguinte, sua paisagem foi transformada em espaços antrópicos, sobretudo pela exploração de seus recursos naturais e pelo espaço cedido para a bovinocultura, expansão urbana, infraestruturas e mais recentemente, para a silvicultura do eucalipto (Itani *et al*., 2011; Trevisan, 2009; Rodrigues e Gandolfi, 2007; Dean, 1996).

No contexto da teoria da Transição Florestal (Rudel et al. 2005), estudo realizado a partir da análise de dados sobre a dinâmica da cobertura florestal no Estado de São Paulo (Farinaci e Batistella, 2012), demonstrou-se que, apesar de haver discrepâncias entre fontes de diferentes institutos de pesquisa e gestão, há indícios de que este Estado esteja passando pelos primeiros estágios da transição florestal, quando os ganhos em novas áreas de cobertura florestal superam as perdas pelo desmatamento. Este estudo também chama atenção para a necessidade de pesquisas mais detalhadas com diferenciação entre mata nativa primária, processos de sucessão florestal e monocultivos florestais como os de eucalipto, informações necessárias para que seja possível monitorar e detectar as mudanças na estrutura e composição da paisagem e da cobertura florestal.

As mudanças no uso e cobertura da terra (LULCC sigla em inglês) são consideradas importante fator sobre as mudanças ambientais, agindo na escala global e regional, com impactos profundos sobre a biodiversidade, conservação dos serviços ecossistêmicos e sobre o clima. Ao redor deste tema, uma diversa comunidade científica se organizou, nas últimas décadas, para desenvolver métodos de pesquisa capazes de lidar com este complexo fenômeno global (Moran e Ostrom, 2005). Há grande variabilidade espaço-temporal nos ambientes biofísicos, atividades socioeconômicas e contextos culturais, associados com as mudanças no uso da terra (Lambin *et al*., 2003).

Os *driving forces* ou "forças condicionantes", importante tópico para as pesquisas sobre LULCC, compreendem os fatores que têm efeitos sobre as trajetórias de mudanças, observadas no tempo e em um determinado local. Em uma tentativa de organizar as pesquisas sobre *drivers of land change*, Bürgi *et al*. (2004) estabeleceram-se cinco grupos a saber: socioeconômico, político, tecnológico, natural e cultural. Desta forma, os estudos das forças condicionantes visam estabelecer as relações entre as causas próximas e subjacentes das LULCC (Brondízio, 2009). As causas próximas representam atividades ou ações imediatas, humanas, que se originam a partir de um interesse sobre o uso da terra e que afetam diretamente a cobertura da terra, enquanto as causas subjacentes, as variáveis demográficas, sociais, culturais, políticas, tecnológicas e biofísicas que constituem as condições iniciais na relação homem-ambiente, são sistêmicas na natureza (Lambin *et al*., 2003; Brondízio, 2009).

Existem diversos métodos para se estudar as dinâmicas de mudanças no uso e cobertura da terra, e são as abordagens referidas como modelos integrados, onde há a possibilidade de reunir os melhores elementos de diferentes métodos, mais apropriados para responder questões específicas (Lambin *et al*., 2000; Lambin e Meyfroidt, 2010). Estudos integrando tecnologias de geoinformação contribuem significativamente para o monitoramento, mapeamento e fiscalização da superfície terrestre, bem como o acompanhamento das reações biofísicas da vegetação em respostas a fatores climáticos e edáficos (Poelking *et al*., 2007). Para compreender as mudanças na paisagem é preciso haver documentação sobre as alterações na cobertura da terra (Batistella e Moran, 2008), além da integração de processos metodológicos que englobem as dimensões sociais e biofísicas da realidade em estudo (Hasperger *et al*., 2010; Wilson, 2008; Tilman, 1999). Finalmente, há uma ampla gama de possibilidades no campo dos estudos conduzidos por meio da integração de dados de sensores remotos orbitais e Sistemas de Informação Geográfica (SIG) com dados qualitativos e quantitativos sobre um determinado fenômeno, região de interesse, ou com as dimensões humanas (Moran e Ostrom, 2005).

Transição Florestal

O desenvolvimento da agricultura, pecuária, expansão das áreas urbanas bem como a instalação de infraestruturas viárias ao redor do mundo, trouxe à superfície terrestre inúmeras mudanças. Estas mudanças se deram sobre ambientes naturais, substituídos por uma ampla variedade de usos da terra. Entre os ambientes naturais alterados ou suprimidos pela ação de ocupação humana, estão as florestas. A Transição Florestal, termo cunhado por Alexander Mather, prevê que uma determinada região, onde ciclos de desmatamento que promoveram a queda expressiva da área de cobertura florestal, em um determinado momento da história, podem seguir caminho contrário, ou seja, o do crescimento e recuperação da vegetação florestal sobre as áreas anteriormente desmatadas, conduzindo a região a um processo de transição para a floresta, onde os ganhos com novas áreas de mata superam as perdas provocadas pelo desmatamento (Mather, 1990; 1992; Mather e Needle, 1998). Derivado de estudos históricos sobre floresta, a teoria afirma que estoques florestais mudam de forma previsível uma vez que a sociedade passa pelo desenvolvimento urbano, industrial e econômico (Rudel *et al*., 2010). Assim, Mather estabeleceu relação causal direta entre o desenvolvimento econômico e a melhora ambiental (Farinaci, 2012), ou seja, após observar ciclos de desmatamento provocados pelas atividades socioeconômicas, como a demanda de madeira para energia, construção, abertura de áreas para produção agropecuária e desenvolvimento urbano, em um determinado momento o ciclo de desenvolvimento econômico passa a exercer influência sobre o modo de vida das populações rurais, favorecendo sua migração para áreas urbanizadas e diminuindo a pressão sobre o uso da terra (especialmente sobre áreas marginais, com pouca adequabilidade para uso agropecuário), e consequente retorno das florestas (Mather e Needle, 1998).

Desta forma, a teoria da Transição Florestal foi desenvolvida no decorrer das últimas décadas, com seus primeiros estudos de caso nas regiões da América do Norte e Europa. Estas pesquisas cunharam duas importantes vias para a transição: a via do desenvolvimento econômico e a da escassez florestal. Em algumas regiões, o desenvolvimento econômico criou empregos não agrícolas fora das áreas rurais que atraiu agricultores para fora da terra, induzindo assim a regeneração espontânea de florestas em antigos campos agrícolas. Em outros lugares, a escassez de produtos florestais ocasionado por altas taxas de desmatamento, levou governos e proprietários de terras a plantar árvores em campos anteriormente ocupados por florestas para restabelecer a oferta de produtos florestais. Dada a amplitude e o caráter generalizador desta abordagem teórica, considerou-se duas vias como meios para se chegar à transição: críticas à teoria e novas propostas de vias, dando maior relevância a contextos locais, regionais, que consideram as dimensões políticas, institucionais, biofísicas e culturais, as quais passaram a ser consideradas (Rudel *et al*., 2005, Lambin e Meyfroidt, 2010; He *et al*., 2014).

Hoje se observa uma ampla diversidade de estudos sobre transição florestal, aplicados a escalas continentais, países e estados, regiões temperadas e tropicais, e levando em conta os mais variados contextos sociais, históricos, biofísicos, culturais, políticos e econômicos (Lambin *et al*., 2003; Sánchez-Cuervo *et al*., 2012; Griffiths *et al*., 2012; Prishchepov *et al*., 2013; Kanianska *et al*., 2014). O que se conclui a partir de todos eles, é que não há vias pré-definidas ou condição *sine-qua-non* para a transição florestal. Este processo e suas variáveis contextuais estão sujeitas à escala de análise, e às dimensões humanas e biofísicas que a permeiam.

A definição de floresta utilizada pela pesquisa

Fotografia tirada em 2014, durante trabalho de campo. Local: Paraibuna.

Os ecossistemas florestais são representados por uma considerável diversidade de formações, como as savanas, cerrados, as florestas tropicais, temperadas; além de uma rica variedade de fitofisionomias, como no caso da Mata Atlântica, por exemplo, composta pelas florestas Ombrófila Densa, Aberta e Mista, Estacional Decidual e Semidecidual, Mangues, Restingas e Campos de Altitude. Há também as "florestas plantadas", como os monocultivos de eucalipto, que correspondem a agrupamentos florestais com finalidade de uso comercial através da exploração de produtos florestais madeireiros e não madeireiros. Para a Organização das Nações Unidas[3], floresta é todo ambiente de terras que se estendem por mais de 0,5 hectare dotadas de altura superior a 5 metros e uma cobertura de copa superior a 10 por cento, ou de árvores capazes de atingir essa altura *in situ*. Esta definição genérica não corresponde à realidade dos ambientes florestais ao redor do globo. Movimentos sociais como o "Movimento Mundial pelas Florestas Tropicais", afirmam que tal definição permite reconhecer os monocultivos florestais, entre eles os de eucalipto, por exemplo, como florestas, quando, na realidade, representam um sistema monocultural menos complexo, biodiverso e integrado à paisagem biofísica que os ecossistemas naturais.

Para os interesses desta pesquisa, realizada na região do Vale do Paraíba Paulista, zona 2 de gerenciamento dos recursos hídricos do Estado de São Paulo, inserida dentro da área de domínio do bioma Mata Atlântica, foram consideradas florestas todas as formações florestais associadas ao bioma, encontradas na região, nos estágios de vegetação primária e secundária desde os estágios iniciais de sucessão florestal. Esta escolha foi pautada na definição de floresta primária e formações secundárias do Conselho Nacional de Meio Ambiente (Resolução CONAMA n^{0} 10 de 1993), em acordo com o Decreto Federal n^{0} 750 de 1993, revogado pela lei n^{0} 11428 de 2006, a Lei da Mata Atlântica, e regulamentada pelo Decreto Federal n^{0} 6660 de 2008. Desta forma, sempre que esta tese se referir à classe de ocupação da terra "floresta", estará abrangendo todas as formações do bioma, nos diversos estágios de sucessão, e protegidas pela Lei da Mata Atlântica.

[3] http://www.fao.org/docrep/013/i1757s/i1757s.pdf.

Florestas plantadas de eucalipto

Fotografia tirada em 2014, durante trabalho de campo. Local: Taubaté.

Foi na primeira metade do século XIX que chegaram ao Brasil as primeiras mudas de eucalipto vindas da Austrália, um gênero (*Eucalyptus*) representado por diversas espécies e que se tornou um dos recursos florestais mais rentáveis e também polêmicos nas últimas décadas do século XX (Vital, 2007). O plantio do eucalipto em escala comercial data da primeira década do século XX (1904). Inicialmente, foi introduzido como monocultura destinada a suprir a demanda de lenha para combustíveis das locomotivas e dormentes para trilhos da Cia. Paulista de Estradas de Ferro (Mora e Garcia, 2000). Dos 470 mil hectares de eucaliptos plantados no país entre 1909 e 1966, 80% concentravam-se no Estado de São Paulo.

A partir de estudos iniciados em 1903, na cidade de Jundiaí/SP, pelo pesquisador Edmundo Navarro de Andrade, com a finalidade de viabilizar o plantio do eucalipto em larga escala, a Cia. Paulista de Estradas de Ferro iniciou os primeiros plantios de eucalipto em escala comercial (Martini, 2010). Apesar do pioneirismo da Cia. Paulista de Estradas de Ferro nas pesquisas para utilização de celulose do eucalipto para a produção de papel na década de 1920, foi no final da década de 1950 que Cia. Suzano marcava o início do comércio internacional brasileiro com produção de papel 100% à base de celulose de eucalipto (Martini, 2010). Esta iniciativa aconteceu frente aos interesses do país em encontrar alternativas à importação da celulose europeia (Mora e Garcia, 2000).

Entre a década de 1960 até o início da década de 1980, houve um grande crescimento das áreas cultivadas de eucalipto para o abastecimento das indústrias siderúrgicas e de papel e celulose, por meio da política de incentivos fiscais ao reflorestamento, adotada pelo regime militar que governou o país entre 1964 e 1985. A partir deste período a área plantada com eucalipto passou de 500 mil para 3 milhões de hectares (Cardoso, 2011). Áreas de floresta nativa foram derrubadas neste período para dar lugar a áreas cultivadas de eucalipto (Freitas *et al*., 2012). Somente em 2010, a silvicultura do eucalipto no Vale do Paraíba Paulista se desenvolveu 24% sobre a vegetação nativa (Carriello e Vicens, 2011). De acordo com Freitas *et al*. (2012), nas décadas anteriores a pressão da eucaliptocultura pode ter sido ainda maior sobre os remanescentes de vegetação nativa.

Até o início da década de 2000, o Brasil era um importador de carvão mineral e coque (fontes de energia imprescindíveis para a siderurgia), sobretudo da China e da Rússia. A partir dessa década, especialmente a China intensifica seu processo de desenvolvimento, com forte componente na construção civil, e torna-se a maior importadora de ferro-gusa e consumidora de suas próprias fontes energéticas, o que levou à diminuição da exportação chinesa de carvão mineral e coque. Esse processo desencadeou uma mudança na correlação de forças no mercado internacional de insumos e produtos siderúrgicos, pois encareceu o valor do coque e do carvão mineral chinês. Isso fez do carvão de origem vegetal um produto rentável e, sobretudo, uma alternativa à compra do coque e do carvão mineral chinês para a siderurgia. Isso permitiu ao Brasil a um ciclo de expansão e consolidação do uso do eucalipto como fonte para a produção de carvão vegetal (Silva *et al*., 2012). Atualmente, o Brasil possui cerca de 5 milhões de hectares plantados com eucalipto (Abraf, 2013).

A segunda década do século XXI está marcada pela expansão da eucaliptocultura em novas fronteiras do território brasileiro (Figuras 1 e 2). Este ciclo de expansão se consolida em regiões onde os custos de aquisição de terras pelas empresas reflorestadoras são mais atrativos que em regiões onde a eucaliptocultura se desenvolveu logo nos seus primeiros ciclos, como nos estados de São Paulo e Minas Gerais. A expansão também é motivada pela demanda de produtos florestais madeireiros, como madeira para construção, movelaria, energia e mais recentemente para produção de biocombustíveis, uma nova era de pesquisa e exploração comercial sobre o eucalipto que se inicia no Brasil.

Em muitas regiões o impacto social e ambiental dos monocultivos de eucalipto se tornou tema amplamente debatido e, por esta razão, o setor florestal passou a incentivar o desenvolvimento de pesquisas científicas bem como a academia e institutos públicos de pesquisa. Houve o surgimento de mecanismos de mercado para a certificação das florestas e maior pressão da sociedade sobre as companhias do setor de papel e celulose, dado os conflitos socioambientais promovidos no campo em decorrência dos monocultivos (Silva *et al*., 2012; Farinaci, 2012; Farinaci *et al*., 2013). Dentre os potenciais efeitos negativos provocados sobre o meio ambiente e sociedade, pelos monocultivos de eucalipto, estão a homogenização da paisagem rural, efeitos sobre a disponibilidade de recursos hídricos, contaminação de solos e águas superficiais pelo uso de produtos químicos no manejo dos monocultivos, degradação de paisagens históricas como a destruição de capelas e construções antigas, impedimento da passagem de romarias por regiões dentro de áreas empresariais cultivadas com eucalipto onde antes havia passagem para tais manifestações religiosas, além do impacto do transporte da madeira nos pequenos bairros rurais circundados pelos plantios (Freitas *et al*., 2012; Silva *et al*., 2012; Farinaci, 2012; Farinaci *et al*., 2013; Eskinazi e Souza, 2013).

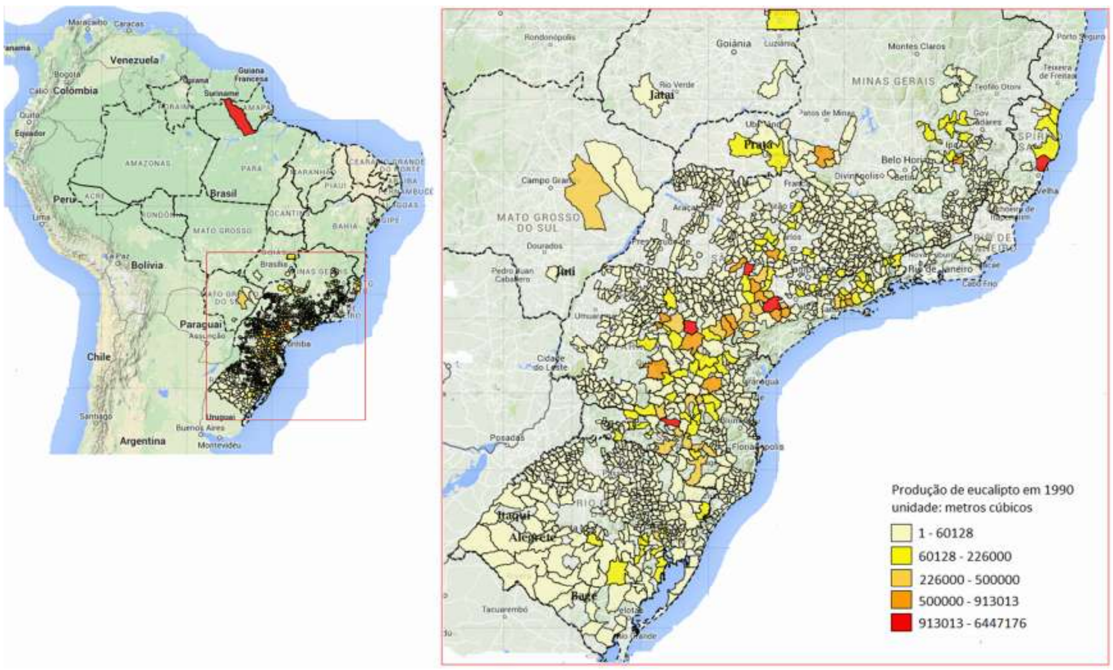

Figura 1. Produção de eucalipto no Brasil, em 1990, com dados espacializados dentro das unidades municipais da federação. Fonte: SOMABRASIL, Embrapa Monitoramento por Satélite.

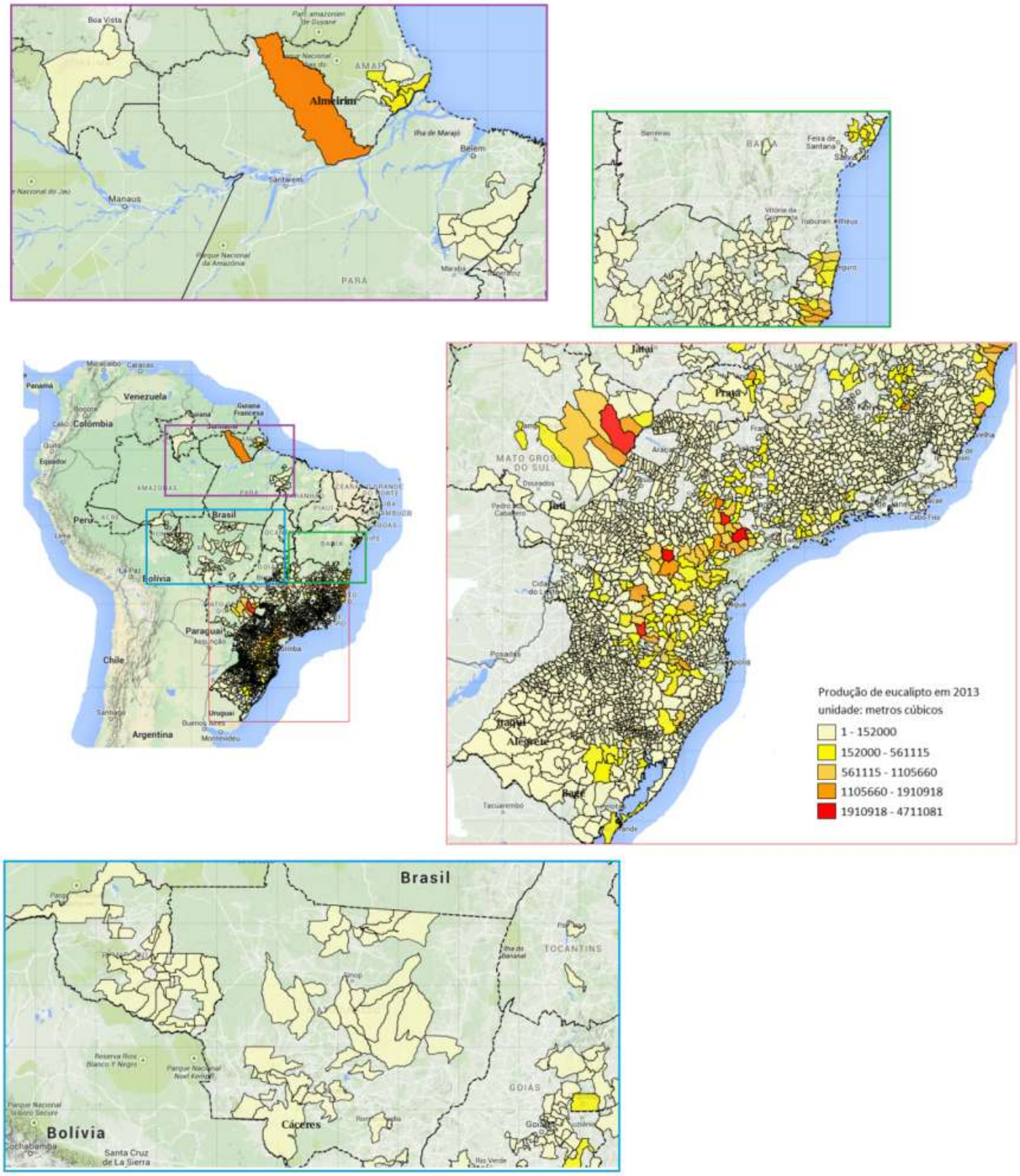

Figura 2. Produção de eucalipto no Brasil, em 2013, com dados espacializados dentro das unidades municipais da federação. Fonte: SOMABRASIL, Embrapa Monitoramento por Satélite.

Como pode ser observado nas Figuras 1 e 2, o eucalipto deixou de se concentrar nas regiões Sul e Sudeste do Brasil para avançar sobre as regiões Centro-Oeste e Norte, especialmente. Este tema, que ganha relevância no cenário econômico brasileiro, bem como desperta interesse da sociedade a respeito dos riscos associados à sua produção, passou a ser regulamentado, a partir de 2014, pela

Política Agrícola para Florestas Plantadas (Decreto Federal n^0 8375). Esta política é um importante marco na consolidação do mercado florestal brasileiro.

Nesta pesquisa, a classe de uso da terra “plantios de eucalipto” representa os monocultivos florestais compostos por espécies arbóreas do gênero botânico *Eucalyptus*. Esta classe, em nenhuma circunstância durante a tese, será considerada floresta natural, como definida pela seção anterior.

O Vale do Paraíba Paulista

Fotografia tirada em 2014, durante trabalho de campo. Local: Bananal.

Aquela que já foi capital econômica do império Brasil, vive e morre, na imponente Serra da Bocaina. Para além do tempo histórico, renasce uma mata, que outrora conhecemos por Mata Atlântica.

(Ramon Felipe Bicudo da Silva)

História, ambiente e sociedade

O Vale do Paraíba, situado entre os estados de São Paulo, Minas Gerais e Rio de Janeiro, foi uma entre as primeiras regiões em território brasileiro ocupadas durante o processo de colonização europeia. Já habitada por diversos grupos indígenas anteriormente, a região sofreu drástica redução de sua cobertura florestal e ambientes naturais, durante o longo processo de ocupação. No princípio do período colonial, a região correspondia ao eixo de ligação entre o Rio de Janeiro com os campos de criação animal no sul do país, quando São Paulo ainda era a povoação de São Paulo de Piratininga, um eixo de conexão entre estas regiões. Com o ciclo do ouro e da mineração (final do século 17 até final do século 18), nos estados de Minas Gerais, Mato Grosso e Goiás, o Vale do Paraíba se tornou importante caminho de passagem entre as minas e os portos de Parati e Rio de Janeiro.

Com a decadência do período minerador, o Vale se tornou menos importante na geopolítica da colônia. Diversas famílias, vindas das “minas” além dos pequenos povoados que ali já estavam fixados, mantiveram a ocupação deste território, sobre tudo com atividades de produção alimentar em escala familiar. Até este momento da história valeparaibana, o desmatamento da Mata Atlântica ainda não é registrado como atividade de significativo impacto sobre as suas florestas.

No entanto, é a partir do início do século XIX, com a chegada do café no Vale do Paraíba, que a região começa a sofrer os primeiros impactos ambientais na escalada da paisagem. Há relatos de queimadas neste período, para a derrubada da mata e abertura de novas terras para a cafeicultura, que duravam dias e deixam povoados inteiros cobertos por fumaça (Figura 3).

Figura 3. "Vista de um Mato Virgem que está se reduzindo a Carvão" (1843) - Félix-Émile Taunay.

“Os incêndios de muitas clareiras elevavam imensas nuvens cinzentas de fumaça. O vale do Paraíba deve ter parecido infernal ao final das estações secas, com centenas de fogos se espalhando por todos os lados [...]. Os viajantes não acostumados com o fenômeno, ficavam surpresos diante da bruma que limitava a visibilidade dos topos das montanhas e que encurtava seu fôlego, provocando–lhes uma sensação de fadiga” (Dean, 1996).

Aqui, quando passou o explorador Richard Burton, na segunda metade do século XIX, fez observações sobre o Vale do Paraíba em relação ao estado de degradação da região, como resultado das práticas agrícolas e de manejo da terra (Richard Burton, 1869):

"As chuvas torrenciais que se seguem aos incêndios anuais levam o humo carbonífero do alto dos morros desmatados para os brejos. Cada corrente é um esgoto de esterco líquido correndo para o Atlântico, e a superfície da terra parece um chão de tijolos.”

O político José Bonifácio, no começo do século XIX, em visita à região, faz o seguinte comentário (José Bonifácio, 1821):

"Todas as antigas matas foram barbaramente destruídas com fogo e machado, e esta falta acabou em muitas partes com os engenhos. Se o governo não tomar medidas enérgicas contra aquela raiva de destruição, sem a qual não se sabe cultivar, depressa se acabarão todas as madeiras e lenhas, os engenhos serão abandonados, as fazendas se esterilizarão, a população migrará para outros lugares."

O que se observou no Vale do Paraíba foi o processo de devastação da Mata Atlântica, também observado em toda a extensão do bioma. A menor área registrada de cobertura florestal para o bioma foi entre os anos de 1985/1990, sendo de 8.8%. Com o declínio da cafeicultura, a região enfrentou um processo intenso de falência das fazendas e famílias cafeicultoras. Seguido por este período decadencial da cafeicultura, as propriedades rurais foram repartidas em unidades menores, como parte da partilha de bens entre as gerações seguintes. Persistindo a degradação do ciclo cafeeiro, a região, no começo de século XX, torna-se produtora de leite. O declínio da cafeicultura teve suas bases não apenas no exaurimento das terras cultivadas na região, especialmente dado às técnicas de manejo como a agricultura de *coivara*[4] (conhecido como "cultivo de corte e queima") e o plantio em alinhamento morro acima, que facilitava o desgaste dos solos, mas sobre tudo pelo fim da escravidão, principal sistema de mão de obra para o café valeparaibano, e a abertura de novas regiões produtoras, balizadas pelo desenvolvimento ferroviário e pelo processo de ocupação do território paulista e nacional.

O ciclo leiteiro ainda se mantém no Vale do Paraíba, no entanto, seu declínio em produtividade é registrado desde o início da segunda metade do século 20. A partir das informações da Pesquisa Pecuária Municipal do Instituto Brasileiro de Geografia e Estatística (IBGE), observa-se que a produção em litros de leite na região pouco cresceu e a relação de produtividade não teve uma grande oscilação positiva ou negativa, contrastando com a realidade do Brasil (Figura 4). Entre os anos de 1990 e 2013, de acordo com a Pesquisa Pecuária Municipal, a produção de leite

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[4] Termo indígena para a prática de abertura de terras para atividade agrícola através do corte da vegetação e sua queima, com fertilização dos solos da terra recém-desmatada pelas cinzas da vegetação queimada (https://www.academia.edu/2034612/Coivara_cultivo_itinerante_na_floresta_tropical).

valeparaibano teve crescimento de +18% com diminuição em -4% na produtividade (Figura 4); já a produção brasileira teve aumento de produção (litros de leite) em +663% com aumento de produtividade em +534%.

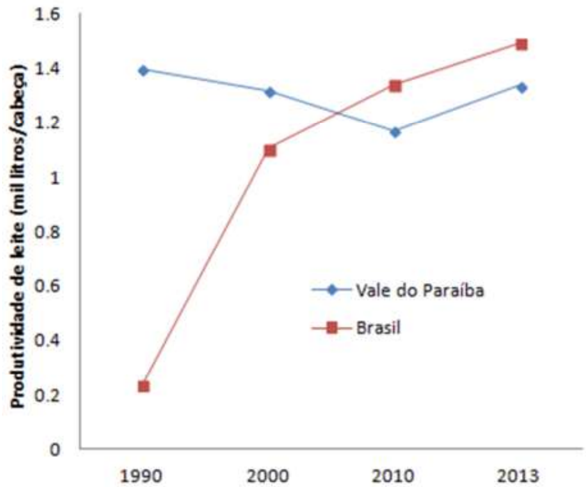

Figura 4. Produtividade leiteira no Vale do Paraíba paulista. Fonte: IBGE (http://www.sidra.ibge.gov.br/bda/pesquisas/ppm/default.asp).

Enquanto o Brasil, entre os anos de 1990 e 2013, de acordo com a Produção Agrícola Municipal[5] (IBGE) teve crescimento de +44% das áreas para a produção de culturas agrícolas temporárias, o Estado de São Paulo registrou crescimento de +50% e o Vale do Paraíba apresentou crescimento negativo de -61%. Em 1990 as áreas cultivadas no Vale representavam 1.5% das áreas cultivadas do Estado. Em 2013 esta proporção caiu para 0.3%. O cenário agrícola e pecuário valeparaibano, de pouca expressividade em relação ao Estado de São Paulo e ao Brasil, também se confirma pela participação da região em relação à sua contribuição em 1.9% no valor adicionado da produção agropecuária do Estado de São Paulo (dados da Fundação Sistema Estadual de Análise de Dados – SEADE. Ano base 2010).

No Vale do Paraíba paulista das últimas décadas, a silvicultura, com base na eucaliptocultura, foi o setor da economia agroindustrial que mais se desenvolveu econômica e tecnologicamente, contrastando com a agropecuária de baixa intensidade e tecnologia, trazendo impactos sobre o uso da terra, ao ambiente e à sociedade. Este setor da economia valeparaibana tem suas bases no ano de 1958, com a instalação da primeira indústria de papel e celulose, na cidade de Jacareí. O turismo cultural, rural e ecológico, ligados ao passado histórico e aos atrativos

[5] http://www.sidra.ibge.gov.br/bda/tabela/protabl.asp?c=1612&z=p&o=28&i=P.

ambientais da região, é considerado uma importante atividade econômica rural do Vale do Paraíba da última década.

Como poderá ser observado ao longo deste trabalho, as transformações ocorridas na paisagem valeparaibana tiveram relações próximas com as mudanças socioeconômicas e culturais vividas pela região, em parte resultado de políticas públicas para o desenvolvimento econômico, conservação e manejo das práticas agrícolas, o desenvolvimento da indústria e do comércio, o êxodo rural e a modernização da agricultura brasileira. Desde o ano de 1985 é observado um padrão ou tendência de queda nas taxas de desmatamento do bioma Mata Atlântica, enquanto o crescimento ou sua recuperação são pouco evidentes na escala estadual (Estado de São Paulo) e nacional (bioma) (Figura 5).

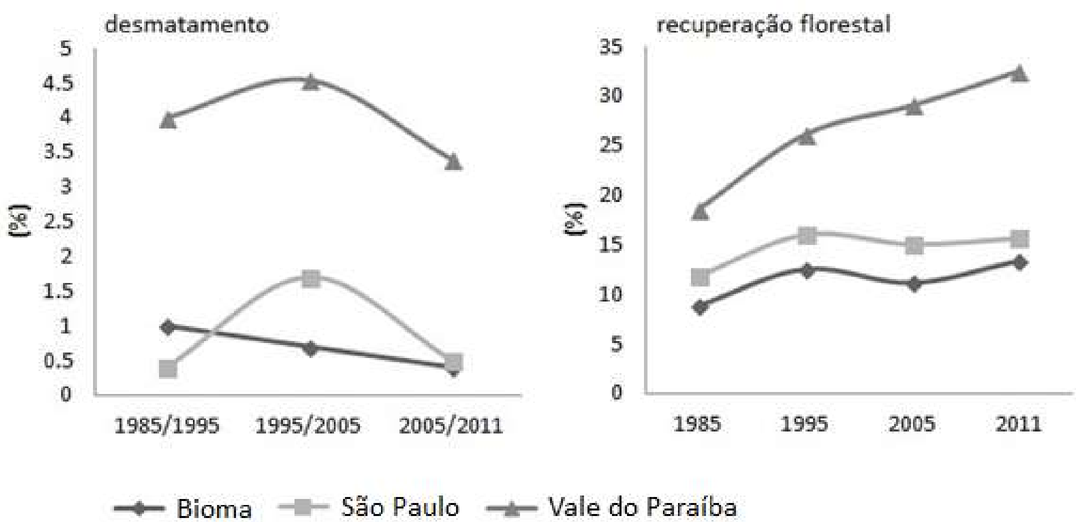

Figura 5. Dinâmica da cobertura florestal (desmatamento e recuperação florestal) para a Mata Atlântica nos níveis de Bioma, Estado de São Paulo e Vale do Paraíba paulista. Fonte: Fundação SOS Mata Atlântica/INPE, 2011.

No entanto, o Vale do Paraíba paulista, região de estudo desta pesquisa de doutorado, compartilha semelhante tendência em relação ao desmatamento e difere das demais escalas em relação à recuperação da cobertura florestal. Estes dados sugerem uma importante consideração: enquanto as taxas de desmatamento respondem de forma semelhante nas diferentes escalas de observação, sugerindo que seu controle esteja ligado a forças condicionantes subjacentes e de ação em nível de bioma, se irradiando para todos os subníveis, a recuperação da cobertura florestal não exibe o mesmo padrão. Neste caso, é possível afirmar que para esta segunda trajetória, forças condicionantes de ação regional ou em subníveis (municípios, por exemplo) da paisagem, têm maior efeito para explicar a dinâmica da Transição Florestal, como poderá ser observado nos capítulos 2, 3 e 4 desta tese, para o caso valeparaibano.

A paisagem biofísica

O Vale do Paraíba Paulista está situado entre duas formações montanhosas, conhecidas por Serra da Mantiqueira e Serra do Mar (Figura 6 e 7). Região descrita por Aziz Ab'Saber (2003) - geógrafo e natural de São Luís do Paraitinga, cidade valeparaibana destacada na conservação de tradições culturais e na postura crítica sobre a exploração do uso da terra pela eucaliptocultura – como "mares de morros", o Vale possui cerca de 63% de sua área de 1.418.964 hectares dominada por terrenos acima de 20% de declividade, ou seja, menos aptos às práticas agrícolas, como a mecanização e irrigação, impedimentos básicos à produção agrícola em larga escala, não representando, necessariamente, obstáculo à prática agrícola de menor escala, tradicional ou tecnificada, desenvolvida na pequena propriedade rural. Suas áreas planas ou com relevos suaves, estão concentradas na parte baixa do vale, cruzada pela rodovia federal Presidente Dutra, principal eixo viário da região e conector das regiões metropolitanas de São Paulo e Rio de Janeiro. Esta zona do Vale também foi onde se desenvolveram os maiores centros urbanos e econômicos, bem como o cultivo de arroz, que nas últimas décadas tem perdido espaço para a exploração de areia (atividade minerária) e especulação imobiliária.

A altimetria da região varia de 600 metros acima do nível do mar, as zonas mais baixas e localizadas nas Planícies Fluviais e Depressão do Médio Paraíba, até máximas de 2000 metros no Planalto da Serra da Bocaina (Itani *et al*., 2011). O sistema hidrográfico da região tem como eixo principal o rio Paraíba do Sul (Planícies Fluviais), possui os reservatórios dos rios Paraibuna/Paraitinga, Santa Branca e Jaguari, além de uma diversidade de rios tributários importantes para o abastecimento da região. Por se tratar de uma bacia hidrográfica interestadual, seus recursos hídricos, que também abastecem parte do Estado de São Paulo, têm função vital no fornecimento de energia e água para a região metropolitana do Rio de Janeiro, com população superior a nove milhões de habitantes.

O Centro de Pesquisas Meteorológicas e Climáticas Aplicadas à Agricultura (CEPAGRI), baseado na classificação Köppen, que considera dados mensais de pluviosidade e temperatura do ar, divide os municípios da região (Figura 6) em três grupos climáticos (Tabela 1).

Tabela 1. Classificação climática de Köppen para os municípios Valeparaibanos. Adaptado de Itani et al. (2011).

Tipo	Características	Municípios
Aw	Tropical chuvoso com inverno seco e mês mais frio com temperatura média superior a 18^0C. O mês mais seco tem precipitação inferior a 60 mm e com período chuvoso que se atrasa para o outono	Aparecida, Bananal, Cachoeira Paulista, Canas, Cruzeiro, Guaratinguetá, Lavrinhas, Lorena, Potim, Queluz
Am	Caracteriza o clima tropical chuvoso, com inverno seco em que o mês menos chuvoso tem precipitação inferior a 60 mm. O mês mais frio tem temperatura média superior a 18^0C	Arapeí, Areias, São José do Barreiro
Cwa	Caracterizado pelo clima tropical de altitude, com chuvas no verão e seca no inverno e temperatura média do mês mais quente superior a 22^0C	Caçapava, Cunha, Guararema, Igaratá, Jacareí, Jambeiro, Lagoinha, Monteiro Lobato, Natividade da Serra, Paraibuna, Pindamonhangaba, Piquete, Redenção da Serra, Roseira, Santa Branca, Santa Isabel, São José dos Campos, São Luís do Paraitinga, Silveiras, Taubaté, Tremembé

Fonte: CEPAGRI (http://www.cepagri.unicamp.br/).

O Vale está inserido no Domínio da Mata Atlântica onde os ecossistemas florestais predominam na composição deste bioma, ocorrendo ainda, em menor proporção, ecossistemas associados às florestas e condicionados à situação geomorfológica – campos de altitude e várzeas. Das trinta e duas legendas de formações vegetacionais para o Estado de São Paulo, vinte e três ocorrem no Vale do Paraíba. Dada a relevância da região em relação à diversidade de formações vegetacionais, esta tem amplas áreas ao largo da Serra da Mantiqueira consideradas prioritárias para a conservação da biodiversidade, de acordo com o programa BIOTA/FAPESP[6]. Ainda, de acordo com o Programa SINBIOTA (BIOTA/FAPESP), há considerável diversidade na fauna da região, distribuída sobretudo nas unidades de conservação que a compõem, entre elas, espécies ameaçadas de extinção, como a onça-pintada (*Panthera onca*), gavião-pega-macaco (*Spizaetus melanoleucus*), lobo-guará (*Chrysocyon brachyurus*) entre outras (Decreto Estadual n^0 56.031 de 2010 que

[6] http://www.biota.org.br/

declara as espécies da fauna silvestre ameaçadas...). Assim, conclui-se que, apesar do bioma ter chegado a níveis críticos de conservação e considerando o histórico de ocupação e uso da terra valeparaibana, a região ainda possui diversidade biológica relevante e, como será demonstrado durante esta pesquisa, capacidade natural de regeneração de suas formações vegetacionais.

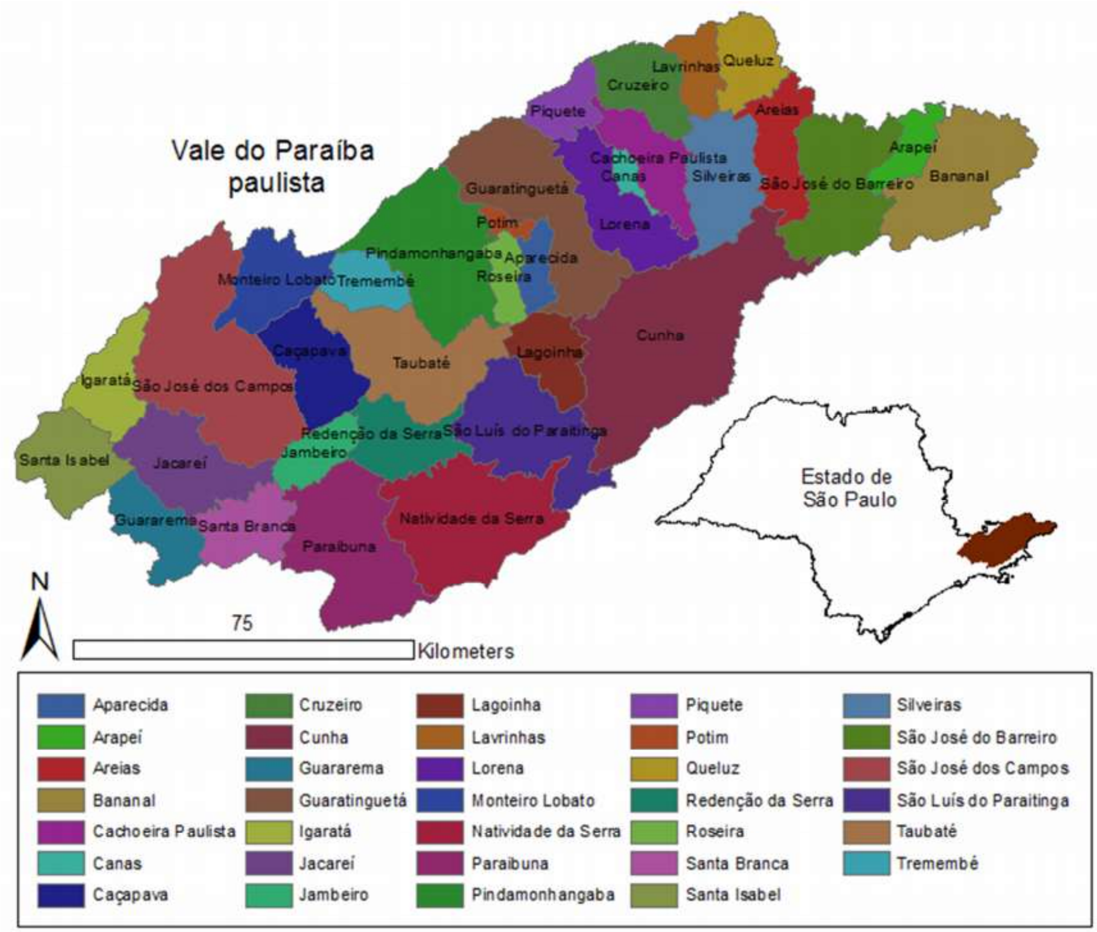

Figura 6. O Vale do Paraíba paulista, UGRHI 02, compreende 34 municípios.

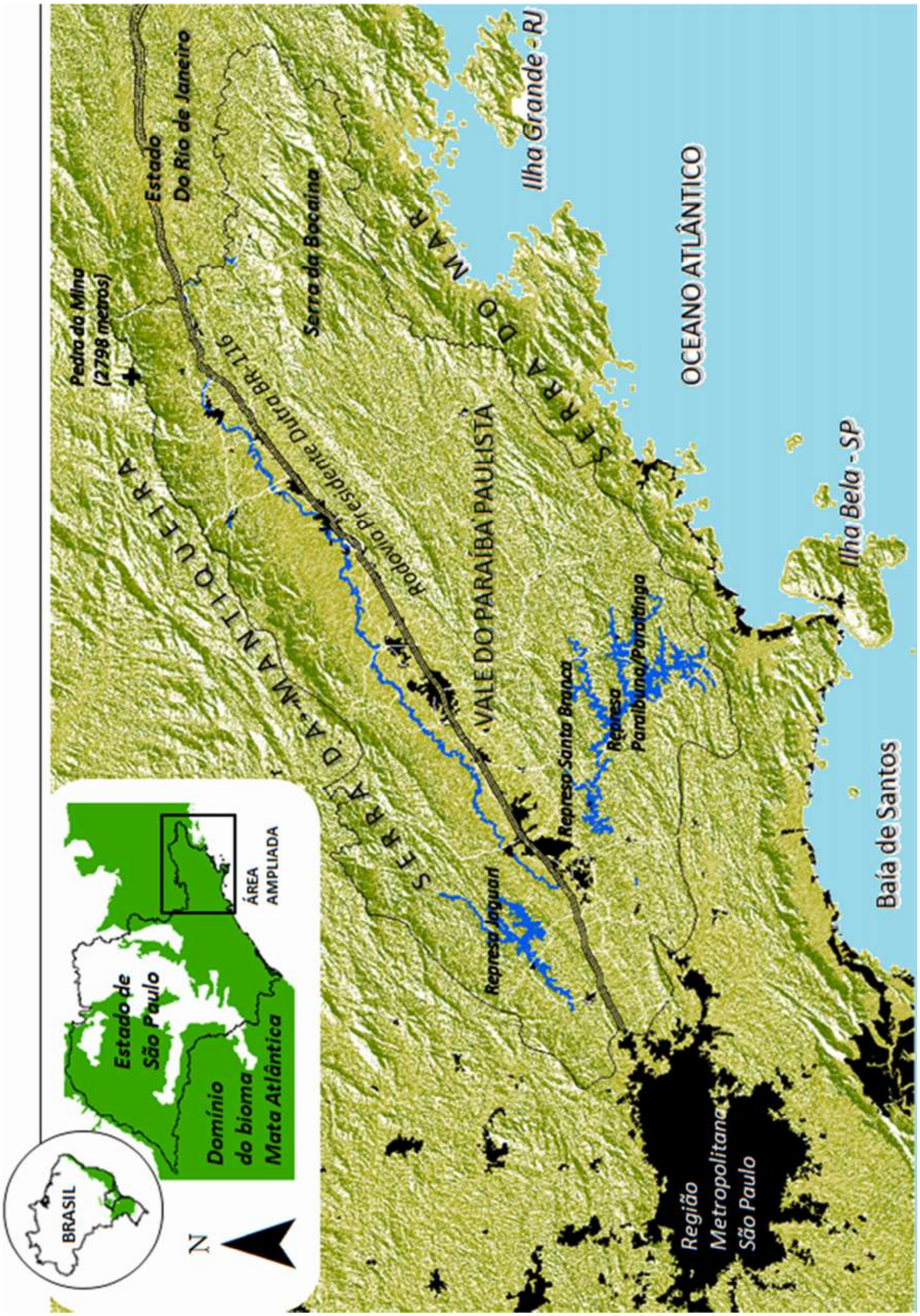

Figura 7. Região de estudo da pesquisa – Vale do Paraíba Paulista.

A pesquisa

Pergunta central da tese de doutorado
Há transição florestal no Vale do Paraíba paulista?

Objetivo central
Entender as conexões socioeconômicas e biofísicas do Vale do Paraíba paulista com o processo de transição florestal.

Objetivos específicos
(a) Mapear o uso e cobertura da terra entre os anos de 1985 a 2011;

(b) Analisar a dinâmica espacial e temporal das mudanças no uso e cobertura da terra, com ênfase na cobertura florestal;

(c) Compreender como os contextos social, econômico e biofísico condicionaram as mudanças na paisagem Valeparaibana ao longo das últimas décadas e contribuíram para a trajetória de índices positivos no crescimento da cobertura florestal.

Hipótese

A transição florestal no Vale do Paraíba Paulista não pode ser respondida integralmente pela via do desenvolvimento econômico. Este é um processo resultante de diferentes fatores biofísicos e humanos que combinados criam o contexto necessário à recuperação da cobertura florestal, tais como o desenvolvimento urbano-industrial, o processo de marginalização do meio rural frente ao processo de "modernização agrícola" brasileiro, a aplicação de políticas ambientais através do Sistema Ambiental Paulista e sua próxima relação com a participação da sociedade, a transformação das propriedades rurais em espaços de turismo e lazer, além do comércio internacional de celulose (de eucalipto) que está atrelado a selos e certificações internacionais de responsabilidade socioambiental.

A tese – estrutura geral

A tese está organizada em quatro capítulos de desenvolvimento teórico e metodológico. Há também a seção de introdução, já apresentada neste documento, além de um capítulo com as conclusões da mesma. Os capítulos de I a IV compõem uma estrutura lógica, cadenciando o desenvolvimento e leitura da tese como um documento organizado em começo, meio e fim. Desta forma, cada capítulo tem importância estratégica para a tese, que os tornam imprescindíveis para a formulação das conclusões finais. Dada a natureza interdisciplinar desta pesquisa, seu desenvolvimento demandou abordagens metodológicas específicas, de modo a atender cada objetivo geral desse trabalho, e assim, ao objetivo e pergunta centrais. A Figura 8 apresenta a estrutura da tese com destaque para a divisão dos capítulos.

Capítulo I. Neste capítulo o enfoque foi para o mapeamento do uso e cobertura da terra. Estas informações foram de suma importância para responder a pergunta central da tese e o objetivo específico (a); bem como trazer as informações sobre as dinâmicas temporais dos usos da terra e sobre a cobertura florestal. Os mapas de uso e cobertura da terra foram elaborados sobre imagens do sensor Thematic Mapper a bordo do satélite Landsat-5, administrado pela Agência Espacial Americana (NASA).

Capítulo II. A partir dos dados de uso e cobertura da terra e das informações secundárias obtidas a partir de fontes públicas de dados – Instituto Brasileiro de Geografia e Estatística (IBGE) e Fundação Sistema Estadual de Análise de Dados (SEADE) – foram desenvolvidas análises espaciais com a variável ***crescimento da cobertura florestal,*** para cada período de mudança (1985-1995, 1995-2005, 2005-2011), a fim de verificar quais variáveis independentes tiveram papel chave para o processo de transição florestal. Junto às informações secundárias, também foram usadas informações físicas da paisagem, obtidas a partir de modelos digitais de relevo. Para analisar as variáveis independentes como o ***crescimento da cobertura florestal***, foram usados dois modelos de análise: (I) regressão logística e (II) o multi-layer perception neural network. Este capítulo foi desenvolvido para atender, principalmente, o objetivo específico (b).

Capítulo III. Com os dados de uso e cobertura da terra, a região valeparaibana foi analisada sobre duas perspectivas: região (Vale do Paraíba Paulista) e sub-região (Médio Vale do Alto Vale do Paraíba Paulista). A fim de enriquecer e aprofundar as análises a partir das informações do uso e cobertura da terra e dados sobre economia, agricultura e população, obtidos junto ao IBGE, dezessete stakeholders, com atuação profissional na região valeparaibana, foram entrevistados. As informações destas entrevistas têm papel fundamental na construção do contexto social e econômico da região, necessárias para explicar as mudanças ambientais observadas nas últimas décadas. Este capítulo procura responder o objetivo específico (c), pois discute os contextos associados às mudanças no uso da terra e ao crescimento da cobertura florestal.

Capítulo IV. A propriedade rural foi a última escala de análise a ser acessada pela pesquisa. O desenvolvimento do questionário estruturado para esta etapa, bem como o desenvolvimento da logística de campo e a decisão sobre as regiões a serem visitadas pela pesquisa, só puderam ser definidas ao longo do desenvolvimento dos capítulos anteriores. Assim, este capítulo não seria possível sem antes terem sido cumpridas as etapas acima mencionadas. Assim como o capítulo III, este capítulo teve fundamental importância para atender o objetivo específico (c). Durante os meses de setembro a novembro de 2014, noventa propriedades rurais (n=90) foram visitadas incluindo a aplicação de um questionário estruturado. Estas propriedades pertencem aos municípios de Taubaté, Bananal e Paraibuna. Em cada um dos municípios o número de amostras foi igual a trinta, totalizando noventa.

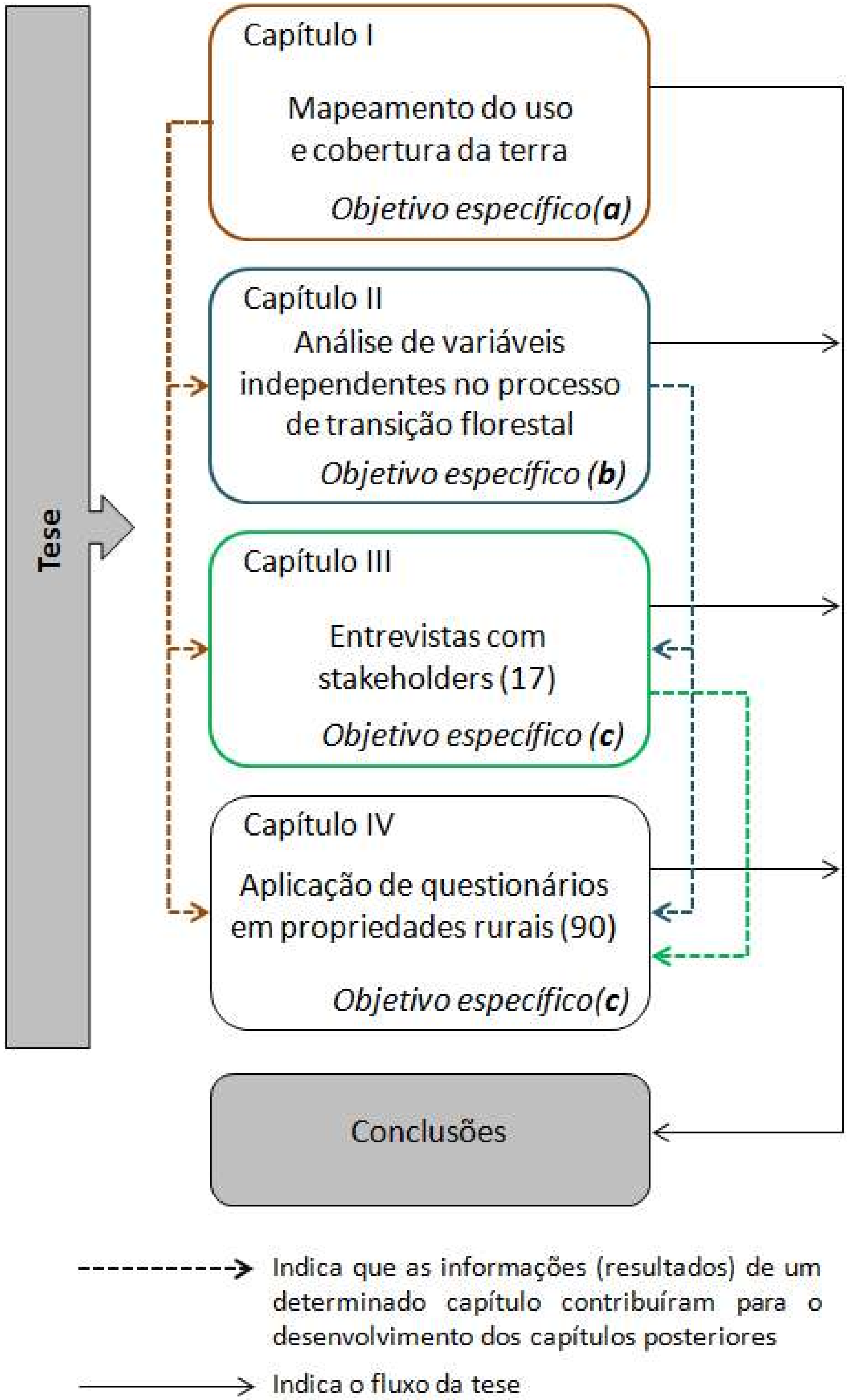

Figura 8. Resumo da estrutura da tese de doutorado.

Referências

Abraf. (2013). Anuário Estatístico *ABRAF 2013* [Statistical Yearbook ABRAF 2013]. Brasília: ABRAF.

Ab'Saber, Aziz Nacib. (2003). Os domínios de natureza no Brasil: potencialidades paisagísticas [The Natural Areas of Brazil: landscape potentialities]. São Paulo: Ateliê Editorial, 6ªed.

Batistella, M., Moran, E. F., eds. (2008) Geoinformação e monitoramento ambiental na América Latina. São Paulo: Editora SENAC.

Boserup, Ester. (1965). The conditions of agricultural growth. New York: Aldine.

Brondizio, Eduardo. (2009). Análise Intra-regional de mudanças do uso da terra na Amazônia. *In* Ecossistemas Florestais: interação homem-ambiente. Moran, E. F.; Ostrom, E., eds. Pp. 289-326. São Paulo: Senac/Edusp.

Browder, J. O. (1992). The limits of extractivism. BioScience 42(3): 174–182.

Bürgi, M., Hersperger, A. M., Schneeberger, N. (2004). Driving forces of landscape change—current and new directions. Landscape Ecology 19: 857–868.

Cardoso, P. (2011). A importância do eucalipto no Brasil. Painel Florestal, Campo Grande, cap. 1, março, 2011.
Disponível em: <http://painelflorestal.com.br/noticias/australia/10971/a-importancia-do-eucalipto-no-brasil> Acesso em: 15 de fevereiro de 2015.

Carriello, F., Vicens, R. (2011). Silvicultura de eucalipto no vale do Paraíba do Sul/SP no período entre 1986 e 2010. Anais XV Simpósio Brasileiro de Sensoriamento Remoto, Curitiba, Brasil. INPE, pg. 6403.

Dean, Warren. (1996). A Ferro e Fogo: História de uso e ocupação da Mata Atlântica. São Paulo: Cia. das Letras.

Eskinazi, B. G., Souza, J. G. (2013). Expertise production and territorial Homogenization: eucalyptus monoculture in the Paraíba Valley and production dynamic changes. Mundo do Trabalho 14(2): 194–211.

Farinaci, J. S., Batistella, M. (2012). Variação na cobertura vegetal nativa em São Paulo: um panorama do conhecimento atual. Revista Árvore 36: 695–705.

Farinaci, Juliana Sampaio. (2012). "As novas matas do Estado de São Paulo": um estudo multiescalar sob a perspectiva da teoria da Transição Florestal [The new forests of São Paulo State: a multiscalar study on the Forest Transition Theory perspective]. Ph.D. dissertation, Department of Environment & Society, University of Campinas, Campinas.

Farinaci, J. S., Ferreira, L. C., Batistella, M. (2013). Forest Transition and Ecological Modernization: eucalyptus forestry beyond good and bad. Ambiente & Sociedade 16(2): 25–44.

Freitas, G. J., Marson, A. A., Solera, D. A. G. (2012). Os Eucaliptos no Vale do Paraíba
Paulista: Aspectos geográficos e históricos. Revista Geonorte 1(4): 221–237.

Griffiths, P., Kuemmerle, T., Kennedy, R. E., Abrudan, I. V., Knorn, J., Hostert, P. (2012). Using annual time-series of Landsat images to assess the effects of forest restitution in post-socialist Romania. Remote Sensing of Environment 118: 199–214.

Kates, R. W., Hyden, G., Turner, B. L. (1993). Theory, evidence, study design. *In* Population Growth and Agricultural Change in Africa. Turner, B. L., Hyden, G., Kates, R. W., eds. Pp. 1–40. Gainesville: University Press of Florida.

Hasperger, A. M., Gennaio, M. P., Verburg, P. H., Bürgi, M. (2010). Linking land change with driving forces and actors: four conceptual models. Ecology and Society 15(4): 1.

He, J., Lang, R., Xu, J. (2014). Local Dynamics Driving Forest Transition: Insights from Upland Villages in Southwest China. Forests 5: 214–233.

IPARDES - INSTITUTO PARANAENSE DE DESENVOLVIMENTO ECONÔMICO E SOCIAL. (2007). Indicadores ambientais por bacias hidrográficas do Estado do Paraná. Curitiba: IPARDES.

Itani, M. R., Barros, C. M., Figueiredo, F. E. L., Andrade, M. R. M., Mansor, M. T. C., Mangabeira, R. L., Carvalho, V. S., eds. (2011). Subsídios ao planejamento ambiental: Unidade de Gerenciamento de Recursos hídricos Paraíba do Sul. Sao Paulo: SAM.

Kanianska, R., Kizeková, M., Novácek, J., Zeman, M. (2014). Land-use and land-cover changes in rural areas during different political systems: A case study of Slovakia from 1782 to 2006. Land Use Policy 36: 554–566.

Lambin, E. F., Geist, H. J., Lepers, E. (2003). Dynamics of Land-Use and Land-Cover Change in Tropical Regions. Annu. Rev. Environ. Resour. 28: 205–241.

Lambin, E. F., Rounsevell, D. A., Geist, H. (2000). Are agricultural land-use models able to predict changes in land-use intensity? Agriculture, Ecosystems and Environment 82: 321–331.

Lambin, E. F., Meyfroidt, P. (2010). Land use transitions: Socio-ecological feedback versus socio-economic change. Land Use Policy 27(2): 108–118.

Martini, A. J. (2010). A Introdução do Eucalipto no Brasil completa 100 Anos. Blog Tudo Sobre Plantas, Rio Claro, outubro, 2010. Seção Artigos, Árvores, Cultivo, Meio Ambiente. Disponível em:
<http://www.tudosobreplantas.com.br/blog/index.php/2010/10/25/a-introducao-do-eucalipto-no-brasil-completa-100-anos/> Acesso em: 15 de fevereiro de 2015.

Mather, A. S. (1990). Global Forest Resources. London: Belhaven Press

Mather, A. S. (1992). The forest transition. Area 24(4): 367–379.

Mather, A. S. and Needle, C. L. The forest transition: a theoretical basis. Area 30(2): 117–124.

Mora, A., Garcia, C. H. (2000). A cultura do eucalipto no Brasil. São Paulo: Sociedade Brasileira de Silvicultura.

Moran, E. F., Ostrom, E., eds. (2005). Seeing the Forest and the Trees: Human-Environment Interactions in Forest Ecosystems. Cambridge: MIT Press.

Moran, Emilio. F. (2011). Meio Ambiente e Ciências Sociais. Sao Paulo: Senac.

Pender, J. L. (1998). Population growth, agricultural intensification, induced innovation and natural resource sustainability: An application of neoclassical growth theory. Agricultural Economics 19: 99–112.

Poelking, E. L., Lauermann, A., Dalmolin, R. S. D. (2007). Imagens CBERS na geração de NDVI no estudo da dinâmica da vegetação em período de estresse hídrico, anais XIII Simpósio Brasileiro de Sensoriamento Remoto, Florianópolis, Brasil, 21-26 abril 2007, INPE, p. 4145-4150.

Prishchepov, A. V., Müller, D., DUBININC, M.; Baumann, M., Radeloff, V. C. (2013). Determinants of agricultural land abandonment in post-Soviet European Russia. Land Use Policy 30: 873-884.

Rodrigues, R. R., Gandolfi, S. (2007). Regrowth actions. *In* High diversity forest regrowth in degraded areas. Rodrigues, R. R., Martins, S. V., Gandolfi, S., eds. Pp. 77-102. New York: Nova Science.

Rudel, T. K., Coomesb, O. T., Moran, E., Achardd, F., Angelsene, A., Xuf, J., Lambin, E. (2005). Forest transitions: towards a global understanding of land use change. Global Environmental Change 15: 23–31.

Rudel, T. K., Schneider, L., Uriarte, M. (2010). Forest Transition: An introduction. Land Use Policy 27: 95–97.

Sánchez-Cuervo, A. M., Aide, T. M., Clark, M. L., Etter, A. (2012). Land Cover Change in Colombia: Surprising Forest Recovery Trends between 2001 and 2010. PLOS ONE 7(8): 1–14.

Silva, R. F. B., Araos-Leiva, F., Farinaci, J. S., Ferreira, L. C. (2012). Monocultivos de Eucalipto, Reflexividade e Arena: Diálogos Interdisciplinares em Ambiente e Sociedade. Terceiro Incluído 2: 32–50.

Tilman, D. (1999). Global environmental impacts of agricultural expansion: the need for sustainable and efficient practices. PNAS 96: 5995–6000.

Trevisan, R. (2010). Estudo do balanço hídrico e da dinâmica do nitrogênio em uma microbacia com plantação florestal de eucalipto no litoral norte do Estado de Sao Paulo. 2010. 111f. Dissertação (Mestrado em Ciências/Química na Agricultura e Meio Ambiente) – Escola Superior de Agricultura Luiz de Queiroz, Universidade de São Paulo, Piracicaba.

Vanwey, L. K., Ostrom, E., Meretsky, V. (2009). Teorias Subjacentes ao estudo de interações homem-ambiente. *In* Ecossistemas Florestais: interação homem-ambiente. Moran, E. F., Ostrom, E., eds. Pp. 41–81. São Paulo: Senac/Edusp.

Vital, M. H. F. (2007). Impacto Ambiental das Florestas de Eucalipto. Revista do BNDES, Rio de Janeiro 14(28): 235–276.

Wilson, G. A. (2008). From “weak” to “strong” multifunctionality: Conceptualising farm-level multifunctional transitional pathways. Journal of Rural Studies 24: 367–383.

Zuquim, M. L. (2007). Os caminhos do rural: uma questão agrária e ambiental. São Paulo: SENAC.

Capítulo I

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Using a Multistage Approach and a Rule Based Post Classification Technique to Evaluate Forest Cover in a Brazilian transitional landscape

Abstract: The research maps land use and land cover distribution in the Paraíba Valley (Atlantic forest biome - Brazil) in 1985, 1995, 2005 and 2011 using a multistage classification approach to detect forest change trajectories using post classification comparison. A series of Landsat-5 Thematic Mapper (TM) images was used for the classification. The Improved normalized difference built-up index (BU) was used as the first stage to classify Eucalyptus plantations. The Maximum Likelihood (ML) method was then used to classify agriculture, built-up areas, water, forest, degraded pasture, managed pasture and bare soil. The multistage approach was compared with two single-stage supervised classification tests using ML and Neural Network (NN). For the training sample collection we built a grid of 43 cells (dimensions: 25 x 25 Km) covering the study area and split 90% of training data for the classification procedure and 10% for validation. The kappa and overall accuracy results for the multistage approach, ML and NN methods for the year of 2011 are: 0.895 and 91.244%; 0.863 and 88.485%; 0.865 and 88.746% respectively. The Eucalyptus plantation class was the only agricultural land use that increased during the study period. The degraded pasture class contributed 74% for the forest cover net gain that agricultural land abandonment is an important driver towards forest recovery in the region. The rates of deforestation reached an average of 3.83% between 1985 and 2011, however, more than 80% of it was concentrated on secondary successional areas. Land trajectories in the Paraíba Valley are under a process of landscape change where gains in forest cover overcome losses by deforestation indicating a forest transition process.

Key words: Forest transition, Landsat-5 TM, Atlantic Forest, multistage classification, land use – land cover.

1. Introduction

The numerous satellites launched over the past four decades have provided a collection of platforms that has been crucial for the study of the environment and the human role in environmental change (Batistella and Moran 2005). Temporal analysis of remote sensing data has demonstrated the influence of human factors on environmental changes, especially in land use and land cover (LULC) (Foley et al. 2005; Moran and Ostrom 2005; Lira et al. 2012). Several studies emphasize the importance of land use and land cover multitemporal classification for various purposes (Lu et al. 2005; Teixeira et al. 2009; Lu et al. 2012; Vaca et al. 2012; Baumann et al. 2012). Several studies conducted for different objectives, such as deforestation control and monitoring (e.g., PRODES – Programme for the Estimation of Deforestation in the Brazilian Amazon), forest cover changes (Key et al. 2011; Sâvulescu and Mihai 2012; Baumann et al. 2012), desertification process or land use and land cover dynamics (Roberts et al. 2002; Hill and Sturm 2007; Lasanta and Vicente-Serrano 2012) demand new methodological approaches.

Multitemporal image classification, a valuable tool for the study of environmental change, requires ancillary data, historical information and good knowledge about the targets and the landscape under study (Serra et al. 2003; Coppin et al. 2004; Lu et al. 2008). However, they are not always available in some cases due to the absence of information, the high cost of data acquisition, or ownership and use rights constraints. These problems, such as the lack of ground truth information for time series, may restrict the use of certain classification procedures and encourage the scientific community to develop different approaches to classify and validate mapping procedures on historical series of images, making this an important research topic (Bruzzone and Cossu 2002; Bruzzone et al. 2003; Baumann et al. 2012).

Studies about forest cover in the Atlantic forest biome have shown remarkable forest cover increase as well as deforestation (Teixeira et al. 2009; Freitas et al. 2010; Lira et al. 2012). Different deforestation rates were observed for the Brazilian states on this biome, indicating a general trend of decline followed by the stabilization of forest remnants (Fundação SOS Mata Atlântica/INPE 2012). However, there are discrepancies among datasets provided by different research organizations and a lack of detailed information about the processes of secondary succession, necessary to understand the landscape dynamics (Farinaci and Batistella 2012). Atlantic forest remnants represent around 13% of the original vegetation cover (Fundação SOS Mata Atlântica/INPE 2012; Ribeiro et al. 2009). It is the Brazilian biome with the highest number of extinct or endangered species and considered a biodiversity hot-spot (e.g., Brazilian list of endangered species of flora); Myers et al. 2009; Machado et al. 2008). The biome hosts the most developed regions of the country, concentrating around 60% of the human population (Fundação SOS Mata Atlântica/INPE 2012). The remnants of this biome play key ecosystem services as influencing how the water is channeled and stored in a catchment, source of medicinal plants, climate control, soil conservation, carbon storage, and aesthetic landscape values (Stasi et al. 2002; Silvano et al. 2005; Ditt et al. 2010; Paula et al. 2011; Villela et al. 2012).

In the Paraíba Valley (within the Atlantic forest biome), Eucalyptus plantations are the land use that has increased the most in recent decades (Itani et al. 2011). The expansion of Eucalyptus plantation in the last decades has led many researchers, decision makers, public agencies and the private sector to search for a better understanding of the impacts of this monocultural system on the environment and society (Whitehead and Beadle 2004; Silveira 2009; Mazzolli 2010; Sell and Figueiró 2011; KrÖger 2012; Farinaci et al. 2013; Almeida et al. 2013). In this context, the mapping of Eucalyptus plantations is an important research topic (Datt 1999; Borges et al. 2004; Soares et al. 2005; Souza et al. 2007; Corte et al. 2008; Arguello et al. 2010; Leite et al. 2012; Maire et al. 2014).

The mapping of Eucalyptus plantation has been extensively explored by medium and high resolution images, and mainly by the methods of visual interpretation, unsupervised classification, segmentation, presenting best performances to the ones applied in high resolution images (Soares et al. 2005; Souza et al. 2007; Corte et al. 2008). High resolution images are expensive and demand a lot of tiles to cover large land surface areas. However, the increasing application of remote sensing for forest monitoring and inventory is seen is a cost effective source of information for the practice of sustainable forest management (Shafri et al. 2007). Therefore, since Brazil is one of the leading countries in terms of Eucalyptus plantations with a cover area around 5 millions of hectares and expectations of increase in the next decades (ABRAF 2013), the use of no cost and medium spatial resolution images as Landsat data (Landsat archive and current Landsat-8 data) still stands as a profitable source of exploration to the remote sensing community, and to manage planted forests.

All these studies deal with current challenges to the interdisciplinary field of environmental sciences and the remote sensing of environment: (*a*) How to improve the quality of classification results aimed at separating natural and planted forests? (*b*) How to deal with the uncertainties inherent in the recovery process of temporal information contained in historical data (series of images) where there are few or any ancillary information from field work or reference data? (*c*) How to identify processes of deforestation and secondary succession using multitemporal classifications?

To address these issues, this article presents an approach to *(i)* land use and land cover multitemporal classification in the Paraíba Valley (Atlantic Forest biome) in 1985, 1995, 2005 and 2011; *(ii)* mapping the spatiotemporal trajectories of the forest cover changes; and finally *(iii)* reduce misclassifications of Eucalyptus plantations, native forest and other vegetation covers to elucidate forest transition processes.

2. Study area

The Paraíba Valley region, encompassed by the *Paraíba do Sul* watershed, spanning the States of São Paulo, Rio de Janeiro and Minas Gerais, has a fundamental role in water and energy supplies to more than 5 million inhabitants. The São Paulo portion of this basin, the Paraíba Valley (Figure 1.1), is a region that covers an area of 14230 km^2, supports a population of over 2 million and represents 4.5% of the Gross Domestic Product (GDP) of the State of Sao Paulo (Itani et al. 2011). The physical landscape is determined by two major geomorphological compartments: the mountainous areas with altitudes up to 2000 meters above the sea level, and convex-concave hills that presents lower unevenness around 200 meters. The region is influenced by the Tropical Atlantic and Polar air masses which cause cold fronts, responsible for part of the annual rainfall average of 1700 mm, mainly concentrated between December and March (Leão 2005).

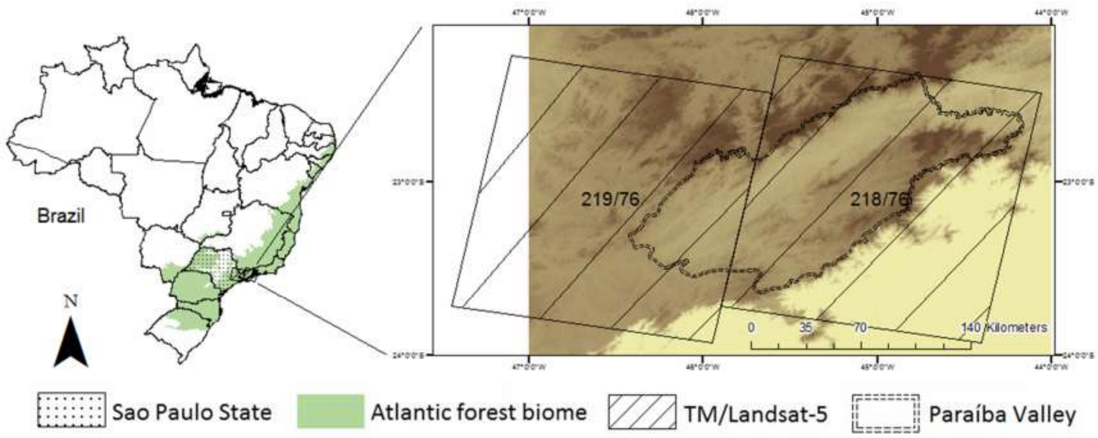

Figure 1.1. The Paraíba Valley within the Atlantic Forest Biome.

In the past, the region was important in producing coffee and milk, and today stands out for industry, particularly in technology and aerospace. With low participation from the rural economy to the region's GDP, the land use that most grew up in recent decades have been the Eucalyptus plantations, mainly for production and international trade of pulp and paper (Itani et al. 2011). The landscape of Paraíba Valley is composed by a matrix of pasturelands with patches of Atlantic forest remnants and Eucalyptus plantations (Arguello et al. 2010).

3. Data and Methods

3.1 Data preprocessing and classification scheme

The dataset consists of a Landsat-5 Thematic Mapper (TM) time series for the years of 1985, 1994, 1995, 2005 and 2011 (scenes 218/76 and 219/76), a set of 43 RapidEye images and field work (Table 1.1). The image preprocessing included registration and atmospheric correction by the Improved Dark-Object Subtraction (DOS2) method (Chavez 1988). Eight LULC classes were defined (Table 1.2) and the classification approach was organized in two stages. Ancillary datasets included elevation and slope maps generated from the *Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model* (ASTER GDEM), the Forest Inventory of the Natural Vegetation of São Paulo State (IF 2005), and the land use and land cover map of São Paulo state in 1994, 2002, 2005 and 2008 (Funcate 2012). The Forestry Inventory of Natural Vegetation was developed with Landsat Thematic Mapper (TM) images of 2000 and 2001, and aerial photos of 2000 and 2001 by visual interpretation, and covering several types of natural forest formations, built-up areas, eucalyptus and water. The LULC maps from Funcate (2012) were generated by visual interpretation of TM images to the classes of pasture, forest, eucalyptus, water and built-up areas.

Table 1.1. Landsat images and other data sources used.

Dataset	Acquisition					
TM Scene 218/76	15 October 1985	24 August 1995	03 August 2005	09 September 2011		
TM Scene 219/76	07 November 1985	27 July 1994	20 April 2005	21 April 2011		
RapidEye	14 April 2011	08 and 23May 2011	16 and 17 August 2011	09, 20, 26 and 27 September 2011	01 October 2011	05 November 2011
Field work	2011 and 2012					
Ancillary dataset						
Aster GDEM	Forest inventory 2001/2002	Funcate 1994, 2002, 2005, 2008				

Table 1.2. Land use and land cover classes.

Classes	Description
Agriculture	areas occupied by annual and perennial crops for food, feed and fuel production, e.g. sugar cane, napier grass, rice, beans and corn
Water	rivers, lakes and dams
Built-up areas	urban, peri-urban areas, highways, industrial areas and other built-up areas
Eucalyptus	monocultural forest plantation with species of the *Eucalyptus* genus
Forest	vegetation formations including stages of secondary succession (shrubland, young forest) and mature forest
Managed pasture	areas used for grazing by cattle for milk and meat production with a predominance of grasses, e.g. molasses grass and Brachiaria sp
Degraded pasture	areas with grasses cover, presence of shrubs, and other herbs, being used as pasture or abandoned
Bare soil	exposed soils associated with agriculture and forestry activities, deforestation or preparation for new built-up areas

To study the changes and dynamics in forest cover by a post classification method, a different classification scheme was developed (Table 1.3). The secondary succession (SS), described as a stage of forest development, in many studies is defined by the subclasses of SS1, SS2 or SS3 based on forest vegetation structure (Lu et al. 2003). For the purpose of the present research, it was developed a method to improve the separability between the forest cover in each period of change. In this case, the subclasses of forest were named as SSA, SSB and SSC. The framework for the research is presented in Figure 1.2.

Table 1.3. Subclasses of forest cover to the Rule Based post-classification method.

Class	Subclasses	Description
Forest (Table 2)	*stable forest*	unchanged forest from 1985 to 2011
	SSA	net gain between one period of change (e.g., 1985 to 1995)
	SSB	secondary forest stage after SSA (SSA → SSB)
	SSC	secondary forest stage after SSA (SSB → SSC)

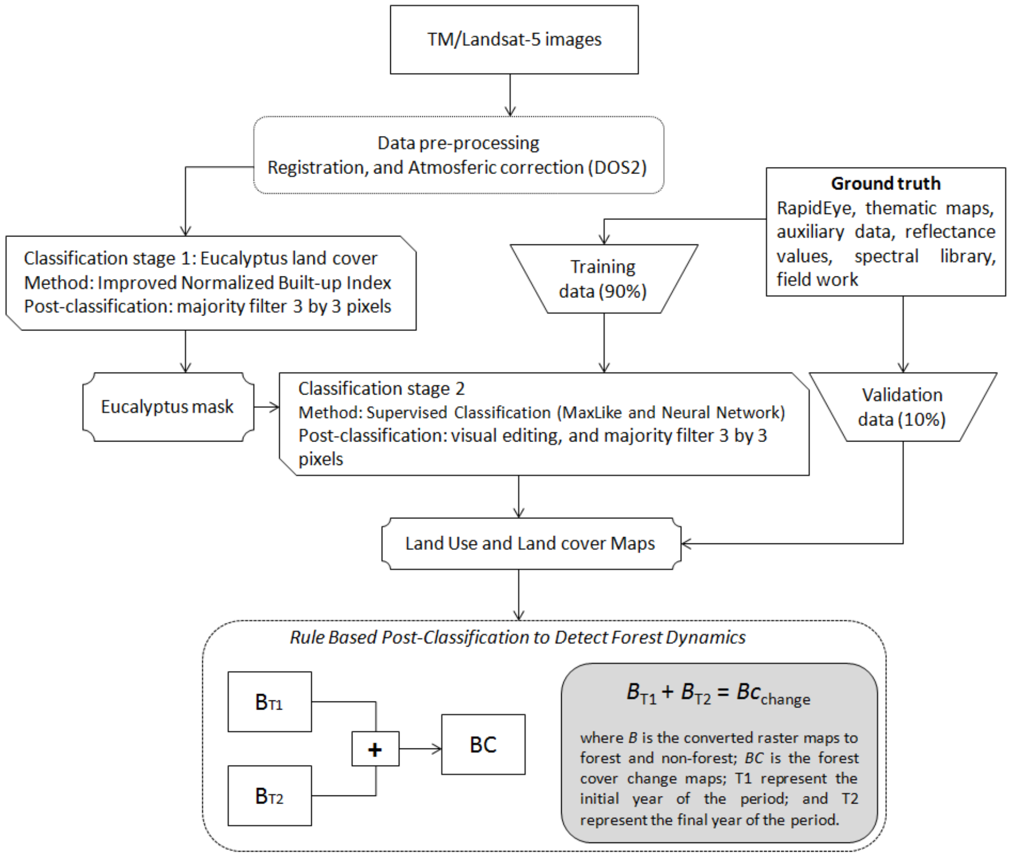

Figure 1.2. Flow chart for the multistage and rule based post classification approach.

3.2 Multistage technique

A multistage classification procedure is considered a series of sub-classifications carried out by masking or omitting certain classes from the classification stages (El-Magd and Tanton 2003). This technique was carried out to optimize the accuracy of the land use and land cover mapping. To accomplish the classification procedure, the class Eucalyptus plantation was classified prior to the supervised classification. For the supervised classification, the Eucalyptus plantation land cover class was used as mask.

3.2.1 Classification, stage 1 (class of Eucalyptus plantation)

The Eucalyptus plantation, defined as a monocultural forest plantation was the first land use to be classified, due to the focus of this research. This land use was classified separately to avoid confusion errors with the classes of forest, agriculture and pasturelands. To classify the Eucalyptus plantation, we adopted the Improved Normalized Difference Built-up Index (BU) method, as suggested by He et al. (2010):

$$NDVI_c = (band4 - band3)/(band4 + band3) \quad (1)$$

$$NDBI_c = (band5 - band4)/(band5 + band4) \quad (2)$$

$$BU_c = NDBI_c - NDVI_c \quad (3)$$

where *c* represents the images in continuous values. The arithmetic manipulations were implemented in TM bands 3, 4 and 5.

For the purpose of this research we did not propose an improvement to the present method of He et al. (2010), however we explore it to classify Eucalyptus plantation. The result is an image (BU_c with continuous values in the range of -2 to 2) where the lower the pixel value is, the greater the probability of this pixel belonging to the class of Eucalyptus plantation. Thus, for the separation of Eucalyptus plantation class, a binary image is created. The threshold search to segment the continuous image was conducted by an empirical strategy, using the BU_c histogram and Eucalyptus training samples collected for supervised classification. The pixel values contained in the training samples of Eucalyptus plantation in the BU_c image were extracted to analysis. The extracted values were checked against the values in the histogram. Based in the pixel values of the samples and the histogram curve was detected in the zone of segmentation between Eucalyptus plantation and forest (Figure 1.3), wherein lie the highest values (BU_c image) of Eucalyptus plantation within the training samples.

This procedure led the analyst to a trial-and-error procedure restricted to a specific range of values in the segmentation zone, starting from the highest value of the Eucalyptus training samples and following to the next in the direction of the lower value of the histogram. Since the trial-and-error procedures require a more experienced image analyst (He et al. 2010), the ancillary datasets of mapping were used to accomplish the threshold search procedure. After the binarization, the result is an image where 1 represents Eucalyptus plantation and 0 others. A majority filter with a window size of 3 by 3 pixels was applied to reduce noise in the classification result. The classification approach was applied for all Landsat-5 Thematic Mapper (TM) image (Table 1.1). Therefore, for each year and scene a respective classification was created for the land use class of Eucalyptus plantation, and applied as a mask in the next classification stage over the respective TM image.

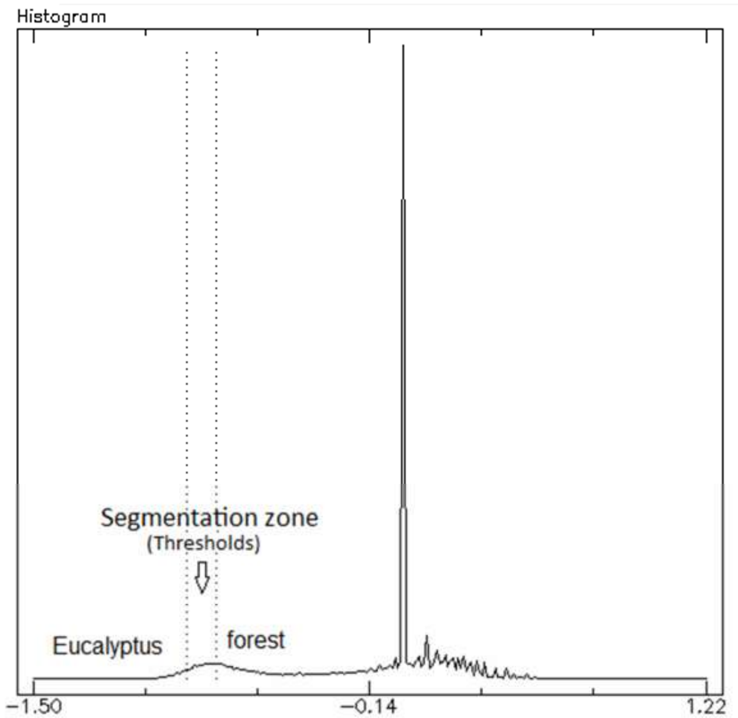

Figure 1.3. Histogram of the BU_c image derived from the mathematical band operations (equations 1, 2 and 3) for the TM image of 2011 scene 218/76.

3.2.2 Classification, stage 2 (other classes)

The result of the first stage was used as a mask over the rest of the study region. Based on the survey to existing pixel-based classification algorithms (Lu and Weng 2007) and suggestions on the selection of classifiers (Shafri et al. 2007; Foody et al. 2007; Mountrakis et al. 2011; Du et al. 2012), two methods - Maximum Likelihood and Neural Network were selected based on their performance (the higher results of Kappa index within a gamma of classifiers applied to the same LULC classification test).

The Maximum Likelihood classifier assumes that the statistics for each class in each band are normally distributed and calculates the probability that a given pixel belongs to a specific class. Unless a probability threshold is selected, all pixels are classified. Each pixel is assigned to the class that has the highest probability. The multi-layered feed-forward Neural Network is used to perform a non-linear classification. Its design consists of one input layer, at least one hidden layer and one output layer (Shafri et al. 2007). The classifiers were performed with a set of training data containing the land use classes. Each TM image (Table 1.1) was performed with a respective set of training data. The classification results for each scene of the same year were mosaicked, generating the LULC map.

3.2.3 Refinements of LULC classification

A comparison between the multitemporal classification images with the Landsat color composites indicated some pixels classified as forest within the Eucalyptus plantation class. To solve this problem, we employed a visual editing procedure: the classified image was overlaid on a corresponding Landsat colour composite. The misclassified pixels were assigned to the Eucalyptus plantation class. The knowledge about the Eucalyptus plantation dynamics in the region was important information for visual editing. Previous research has identified that the Eucalyptus plantations grew from the 1980s until the 2000s in the Paraíba Valley, remaining stable in many regions since the 1980s (Itani et al. 2011; Freitas Junior et al. 2012; Neves et al. 2013). Over this map it was applied a majority filter with a window size of 3 by 3 pixels to re-assign a LULC class to the center of the pixel.

3.3 Training data

The RapidEye imagery of 2011 as well as field work (2011 and 2012) data were used to define the training data for the supervised classification of 2011. The entire region is covered by a set of 43 RapidEye tiles (25km by 25km dimensions). The training data for the eight classes (Table 1.2) were sampled in all RapidEye images using interpretation of high-resolution images. The field work used *in situ* inspection to access ´ground truth´ information and validate the training data. Based on the training data of 2011 (reference data), two steps were carried out to define the training data for the retrospective TM imagery: *(i)* Spectral library and preliminary maps; and *(ii)* training data collection to the retrospective TM imagery.

(i) From the set of training samples for the 2011TM images, we built a spectral reference library from the spectral signatures of the LULC classes. By the Spectral Angle Mapper (SAM) classification algorithm, the spectral library was used to classify the time series of TM/Landsat-5 images. The SAM is a classification method for feature spectra based on a comparison of the spectral image with a reference spectrum (endmembers or spectral libraries) (Shafri et al. 2007). The purpose of the classification by SAM was to generate preliminary maps to serve as support information to collect training samples for each class in the time series. This cascade classification procedure explores the existing temporal correlation between images acquired at different dates (Bruzzone and Cossu 2002).

(ii) The 2011 spectral reference data were then used to examine the field and spectral response patterns of the corresponding TM images in the time series to derive reference data for 1985, 1995 and 2005 LULC classes. Each area used for 2011 was checked against the TM images in the time series and with the preliminary maps generated by the SAM classifier, thematic maps (ancillary dataset), as well as elevation and slope maps (ASTER GDEM) to assure that the general LULC classes were the same. Based on this survey, the training data for 1985, 1995 and 2005 that did not match the correspondent LULC classes in 2011 were discarded from the reference data. The topographic information from the ASTER GDEM is a valuable source to distinguish forest and agricultural areas in the Paraíba Valley. As observed in previous works (Mello 2009; Itani et al. 2011; Farinaci 2012), there is a pattern of forest cover location in the Paraíba Valley, more related with steep slopes and high altitudes, and more concentrated in the borders of the Valley, as well as the agricultural areas in the major floodplains following the Paraíba do Sul river. This knowledge gave additional information for visual interpretation of forest landscape patterns, and agricultural areas in floodplains. To evaluate the method's reliability for the multitemporal classification, two procedures were adopted:

(1) Each set of training samples in the time series generated a spectral library from the reflectance information contained in the respective images. Then the mean reflectance values were calculated for each class in the 6 bands (1, 2, 3, 4, 5, 7) for each year, and plotted in graphics.

(2) Between the years of 1985, 1995 and 2005 the mean and standard deviation for each class were calculated, and a two-tailed hypothesis test with a significance level of 1% was applied to evaluate the compatibility between the reflectance values of each class in the 6 bands with the average reflectance values of the same classes and bands in 2011.

3.4 Accuracy assessment

The set of validation samples and the LULC maps generated results for overall accuracy, kappa index, producer´s accuracy and user´s accuracy. These parameters were calculated from the error matrix (Foody 2002). We used 6603 validation samples for 2011, 6062 for 2005, 5648 for 1995, and 6109 for 1985. The results of the multistage technique were compared with those obtained using Maximum Likelihood

(ML) and Neural Network (NN) procedures. The statistical significance level of the difference in accuracy (kappa coefficients) between the multi and single-stage classifications was carried on by the Z test at the 5% level of significance (Hudson and Ramm 1987), where the difference between two kappa coefficients derived with related samples would be regarded as being statistically significant if the computed proportion was less than 0.05 (Foody 2004).

3.5 Rule based post-classification technique (forest cover change)

There is a great need for detailed research to differentiate primary native forest and secondary succession (SS), fundamental information to monitor and detect changes in the structure and composition of the forest landscape (Farinaci and Batistella 2012). The processes of secondary succession (SS) are those where there is regeneration of native forest vegetation, in a natural way or by reforestation (Pillar 1994; Magnago et al. 2011).

To classify secondary succession and define the remaining unchanged vegetation during the study period, a Rule Based Post-Classification was used (Serra et al. 2003). For this research, as already adopted in other studies (Espírito-Santo et al. 2005; Baumann et al. 2012), the forest cover in 1985 was considered the initial state of forest from which changes were detected, and called as “stable forest”. To track forest cover changes in each period, a mathematical band operation was applied. In the LULC maps (raster format), all classes were converted to the value 0, except the forest class, which was converted to the value 5 (1985); to the value 10 (1995); to the value 20 (2005); and to the value 40 (2011).

Then, one by one, the converted raster maps were added according to the equation (4), and Figure 1.4.

$$B_{\mathrm{T1}} + B_{\mathrm{T2}} = BC_{\mathrm{change}} \quad (4)$$

where *B* is the converted raster map to forest and non-forest; *BC* is the forest cover change map; T1 represent the initial year; and T2 represent the final year.

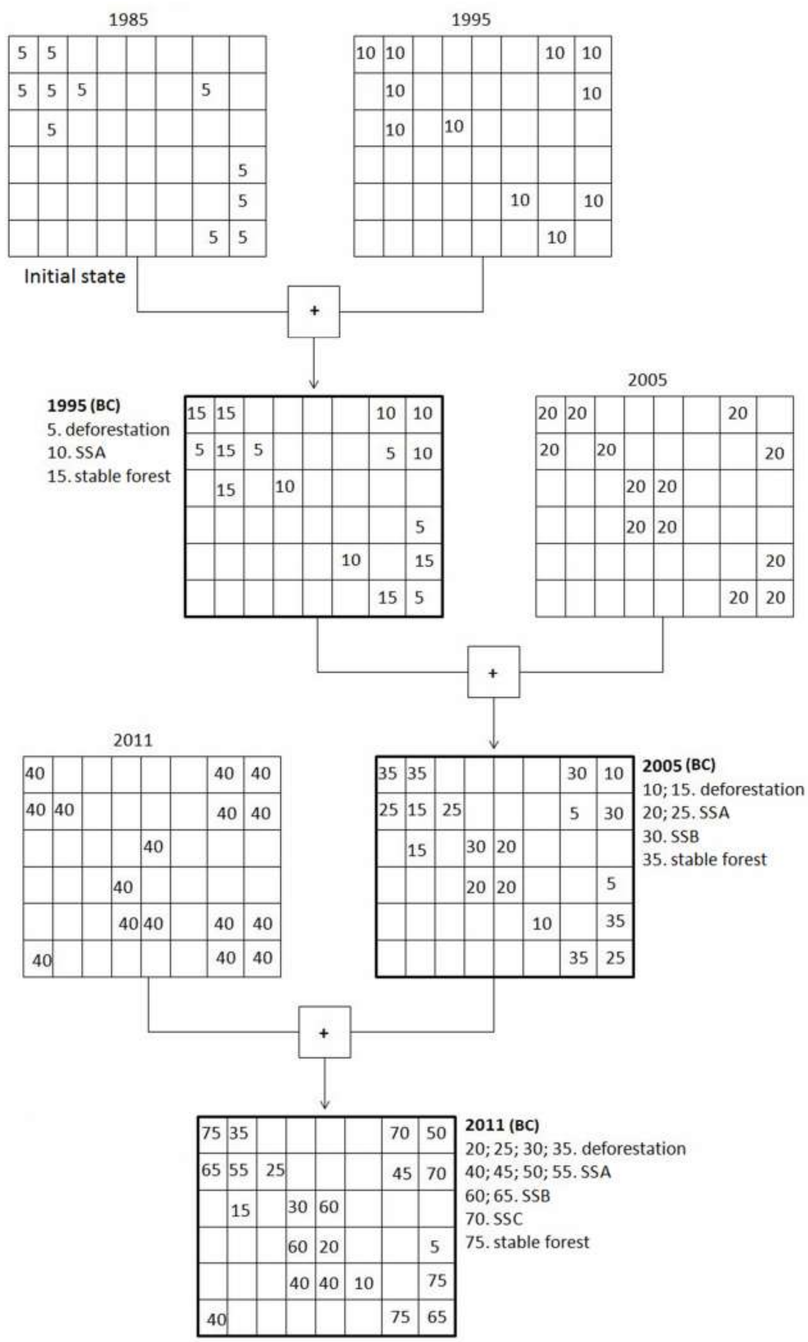

Figure 1.4. Rule based post-classification technique to detect forest cover change in the Paraíba Valley (1985-2011). SSA represents the initial stage of secondary succession, SSB is the remained secondary succession during a second period of change, and SSC is the remaining secondary succession for a subsequent period of change.

Residual values were found for the results of 2005(BC) and 2011(BC) (Figure 1.4). They represent the deforestation process observed during the previous change period. Thus, deforestation observed in 1995(BC) was disregarded in the computation areas of deforestation in the 2005(BC); the deforestation observed in 2005(BC) was disregarded in the computation areas of deforestation in the 2011(BC). The results obtained by the maps of change (BC) were overlaid with the LULC maps to identify the deforestation process and the trajectories of changes between land use and forest classes.

4. Results

4.1 Classification of Eucalyptus plantation

The BU_c image resultant from the digital processing stage 1 (*3.2.1*), highlights the contrast among the response patterns of different land covers. The highest $NDVI_c$ values are attributed to the land use class of Eucalyptus plantation. The lowest $NDBI_c$ values are attributed to the land use class of Eucalyptus plantation. In the formula (3) these values were summed giving the lowest values to Eucalyptus plantation class, BU_c image (Table 1.4, Figure 1.5). This approach increases the differences in the pixels values between this land use class and the Atlantic forest remnants, the land cover class that has similar patterns of vegetal spectral responses in the bands 1, 2, 3, 7 and differing in the bands 4 and 5 of the Landsat-5 Thematic Mapper as shown in Figure 1.6.

Table 1.4. The table shows the pixel value for Eucalyptus plantation and Atlantic forest remnant for each image in a known sample of the TM image in the study region. The BU_c image the difference between Eucalyptus plantation and forest is greater than the others, highlighting the increase in the contrast between these two classes achieved by the improved normalized difference built-up index. The same pixel of each class is presented for each transformed image, NDVI, NDBI and BU.

	Pixel values		
	$NDVI_c$	$NDBI_c$	BU_c
Eucalyptus	0.7475	-0.4285	-1.176
Forest	0.6065	-0.1666	-0.773
Difference	0.1418	0.2619	0.4037

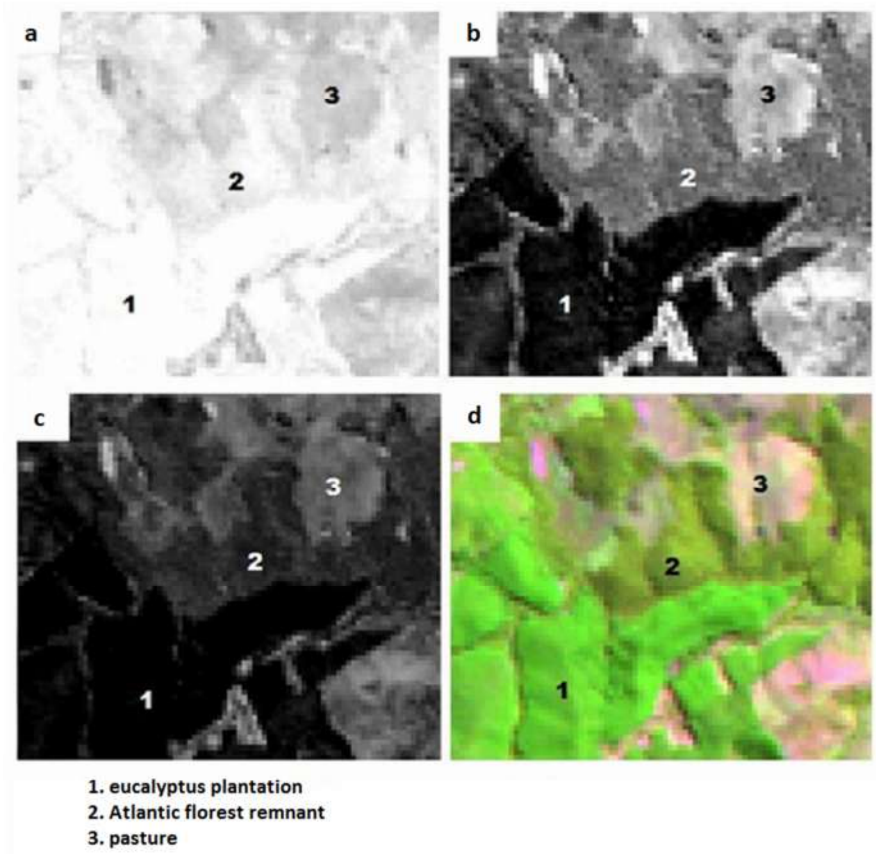

Figure 1.5. Image subset for the $NDVI_c$ image (a), $NDBI_c$ image (b), BU_c image (c), and TM/Landsat-5 color composite (d).

Thus, the subtraction proposed by equation (3) enhanced the difference between the values for Eucalyptus plantation and forest, and then the procedure to determine threshold values to the BU_c image binarization was conducted (Table 1.5).

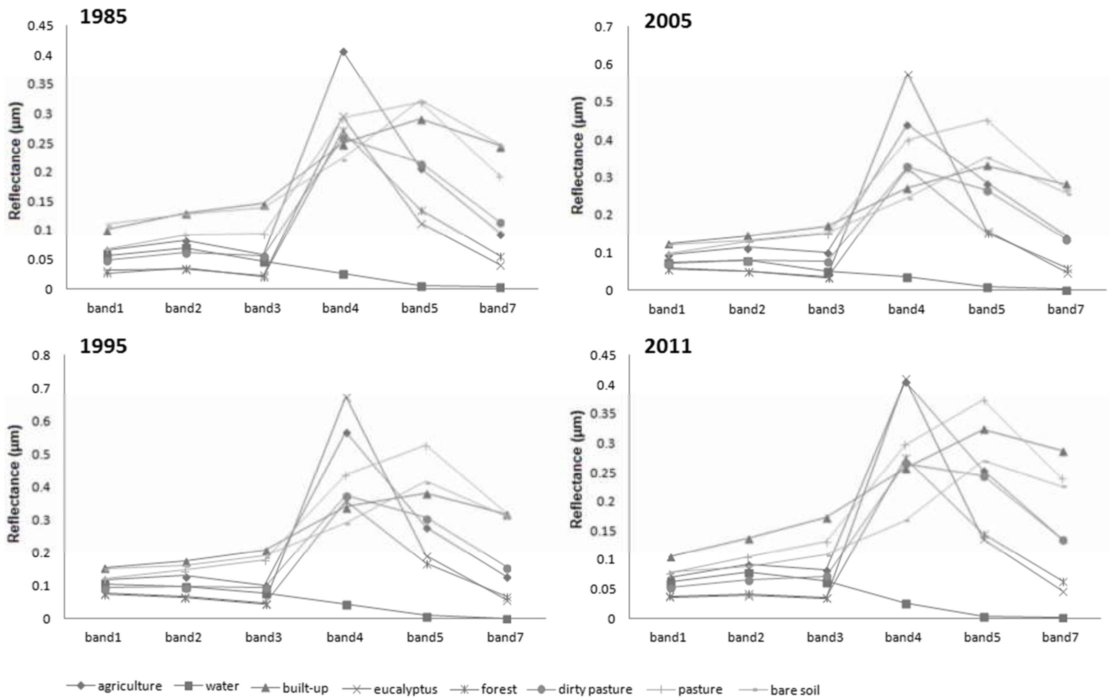

Figure 1.6. Average reflectance values for each LULC class.

Table 1.5. Threshold values to the image (BU_c) binarization.

	Threshold	
Year	218/76	219/76
1985	-0.85	-0.89
1995	-0.89	-0.91
2005	-0.91	-0.92
2011	-0.90	-0.95

4.2 LULC and accuracy assessment

The multistage procedure adopted for the LULC mapping in the Paraíba Valley provided results with better accuracy compared to single-stage classification procedures (Table 1.6).

Table 1.6. Results of kappa index and overall accuracy for the LULC maps by the multistage technique, and the single-stage Maximum Likelihood (ML) and Neural Network (NN) supervised classifications. * Difference between two Kappa coefficients (Multistage X Single-stage) statistically significant at 5% confidential level (α = 0.05).

	Kappa			Overall accuracy (%)		
		Single-stage			Single-stage	
LULC maps	Multistage	ML	NN	Multistage	ML	NN
1985	0.897*	0.879*	0.884*	91.654	90.153	90.561
1995	0.899*	0.881	0.876*	91.554	90.067	89.695
2005	0.902	0.875	0.881	91.685	89.294	88.821
2011	0.895*	0.863*	0.865*	91.244	88.485	88.746

The ML supervised classification algorithm was chosen because it provided accurate results as the Neural Network classifier and it is less time consuming than NN. This algorithm was combined with the BU method in a multistage technique for the LULC classification. By the multistage classification improvements in accuracy assessment were observed (Table 1.6) compared to the single-stage methods. Producer's and User's accuracy, and Commission and Omission errors for 2011 (Table 1.7) show improvement in the accuracy by the multistage technique. The Z test to measure statistical difference between the Kappa coefficients of the multistage classification compared to the singe-stage methods presented statistical significance for the years of 1985, 1995 and 2011 (Table 1.6). These results indicate that the multistage technique performs more accurate classifications than the single-stage methods, and is statistically significant at 5% confidential level (Z significant p≤0.05). Table 1.8 shows the percentage of each LULC class in the time series.

Table 1.7. Producer's and User's accuracy for each classification approach in 2011.

	Prod. Acc. (%)			User Acc. (%)		
		Single-stage			Single-stage	
	Multistage	ML	NN	Multistage	ML	NN
Agriculture	67.44	73.84	61.63	95.08	83.01	89.83
Water	79.19	79.19	79.31	99.98	99.98	99.98
Built-up	98.00	96.00	95.83	98.51	98.15	98.12
Eucalyptus	95.15	89.75	93.64	96.71	94.55	91.95
Forest	98.25	92.73	92.92	95.02	91.22	93.26
Managed pasture	91.51	89.81	93.83	92.95	91.51	87.36
Degraded pasture	90.64	85.96	66.67	74.52	66.52	79.72
Bare soil	82.86	84.29	85.24	94.05	86.76	83.26

Table 1.8. LULC classes through time.

LULC classes	%			
	1985	1995	2005	2011
Agriculture	3.75	1.44	4.02	3.68
Water	1.68	1.43	1.87	1.86
Built-up areas	2.74	3.16	3.21	3.86
Eucalyptus	2.58	3.99	3.37	6.15
Forest	18.58	25.96	28.77	32.18
Managed pasture	27.77	18.72	21.22	27.79
Degraded pasture	39.24	42.94	35.82	23.43
Bare soil	3.66	2.36	1.72	1.05

4.3 Training samples and LULC spectral signatures (hypothesis test)

The hypothesis test was used to assess the compatibility between the training samples for the entire time series assuming the reflectance values contained in the training samples for 2011 as reference data. For the hypothesis tests with a significance level of 1%, all classes, except the bare soil, had the null hypothesis (H_0: $\mu = \theta$) not rejected, for a total of 48 tests (6 hypothesis tests for each class in the TM bands 1, 2, 3, 4, 5, 7), Table 1.9. By the hypothesis test, the sets of training data showed coherent levels of reflectance in the time series.

Table 1.9. Results for the hypothesis tests applied in the band 4 for all classes. The same test was applied to the bands 2, 3, 4, 5, 7 of the TM/Landsat-5. SUM is the addition of the mean reflectance values for 1985, 1995 and 2005. AVERAGE is the average value for 1985, 1995 and 2005. SD is the standard deviation. ME is the margin of error. UL is the upper limit of the two-tailed hypothesis test. LI is the lower limit of the two-tailed hypothesis test. The value of confidence interval (Z) at 1% was 2.53.

Band 4	1985/1995/2005						2011	Result
	SUM	AVERAGE	SD	ME	UL	LI		
Agriculture	1.4141	0.4713	0.0838	0.1248	0.5962	0.3464	0.4046	H_0: μ=θ
Water	0.1052	0.0351	0.0084	0.01260	0.0476	0.0224	0.0265	H_0: μ=θ
Built-up	0.8604	0.2868	0.0475	0.0708	0.3576	0.2159	0.2574	H_0: μ=θ
Eucalyptus	1.5431	0.5143	0.1958	0.2917	0.8061	0.2225	0.4099	H_0: μ=θ
Forest	0.9499	0.3166	0.0428	0.0638	0.3804	0.2528	0.2745	H_0: μ=θ
Managed pasture	1.1313	0.3771	0.0752	0.1120	0.4891	0.2650	0.2973	H_0: μ=θ
Degraded pasture	0.9611	0.3203	0.0579	0.0863	0.4066	0.2339	0.2653	H_0: μ=θ
Bare soil	0.8061	0.2687	0.0541	0.0805	0.3492	0.1881	0.1679	H_1: μ≠θ

4.4 Forest cover change

From the 1985, 1995, 2005 and 2011 LULC maps forest cover changes were detected, generating the SSA, SSB, SSC and stable forest subclasses (Table 1.10, Figure 1.7). According to the Table 1.10, the rates of deforestation were 3.51% for the period between 1985 and 1995, 4.54% for the period between 1995 and 2005, and 3.44% for the period between 2005 and 2011.

Table 1.10. Forest cover change in the Paraiba Valley between 1985 and 2011.

	%			
Forest subclasses	1985	1995	2005	2011
SSA		10.96	7.38	7.13
SSB			7.34	5.26
SSC				6.18
Stable forest	18.58	15.01	14.07	13.61

New forest areas developed mostly over classes of degraded pasture and managed pasture in the proportions of 74% and 11%, respectively. The subclass stable forest from 1985 remained 88% of its cover stable during the period of study. The Eucalyptus plantations replaced areas of degraded pasture, managed pasture and forest in the proportions of 48%, 29% and 13%, respectively. Deforestation, which has an average rate of 3.83% for the three periods of change, shows a decreasing trend for the more advanced stages of secondary succession and for the stable forest (Table 1.10).

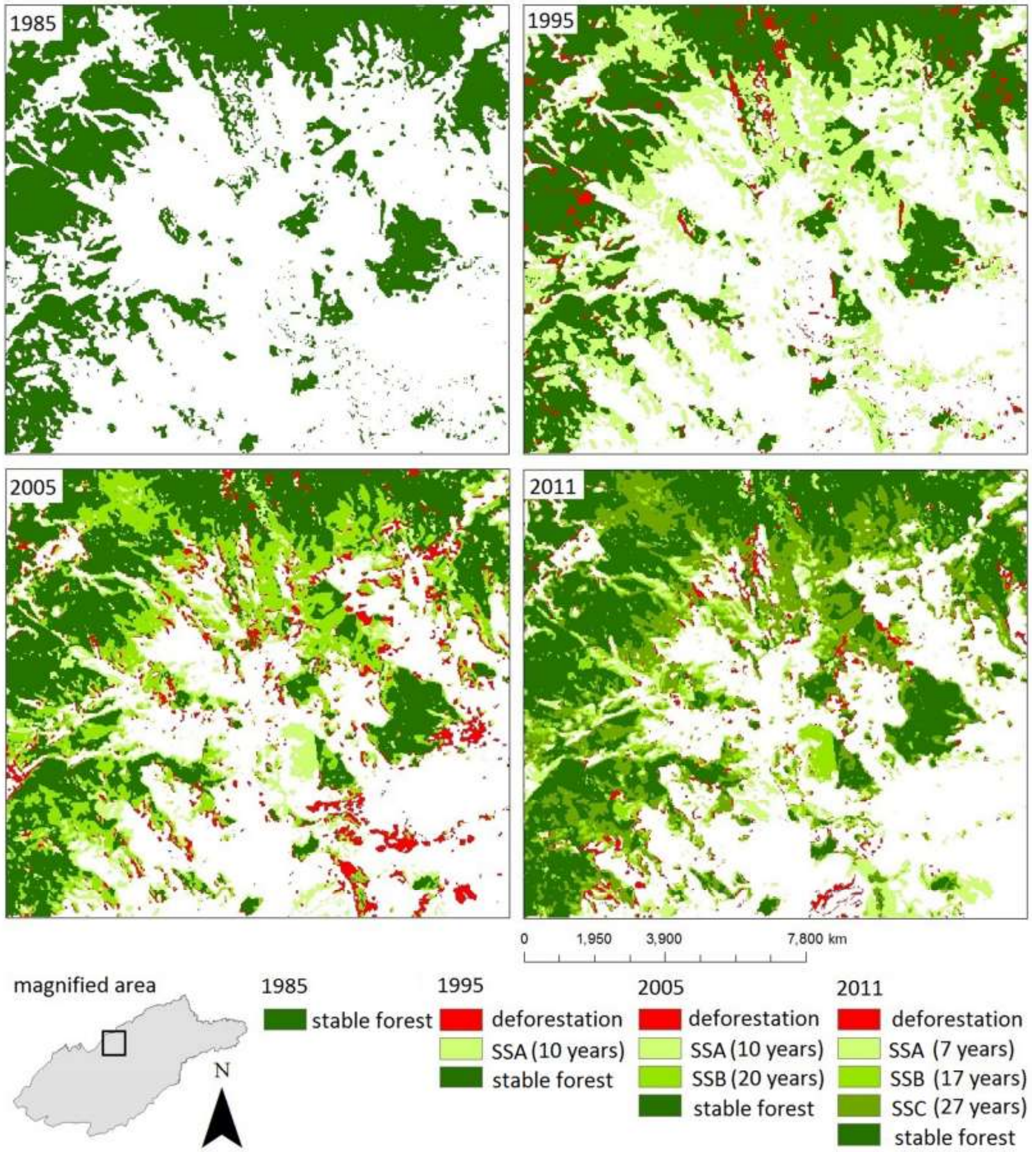

Figure 1.7. Forest cover and secondary succession between 1985 and 2011 in the Paraíba Valley.

Deforestation rates for the sub-class stable forest decreased to 0.5% between 2005 and 2011. At the same time, a trend in deforestation in secondary successional areas (SSA) was observed. Between 1995 and 2005 the deforestation rates on SSA subclass was 3.62% while 0.3% on stable forest; Between 2005 and 2011 the deforestation rates were 2.12% on SS1, 1.16% on SSB, and 0.46% on stable forest subclasses. Table 1.11 shows the contribution of each class to the deforestation rates. The main trajectories for the forest cover change are summarized in Figure 1.8.

Table 1.11. Rates of deforestation caused by different LULC classes. Degraded pasture and managed pasture were grouped (pasture) to present a single value for pastureland.

	%		
Contribution for deforestation from	1985/1995	1995/2005	2005/2011
Agriculture	0.3	1.4	2.8
Bare soil	1.1	1.3	0.1
Built-up areas	0.6	2.6	1.5
Eucalyptus	30.2	13.8	38.1
Pasture	67.3	77.1	56.3
Water	0.5	3.8	1.2

The change analysis allowed us to identify the pressure of Eucalyptus plantations on deforestation rates during the period of analysis, especially in its role on the deforestation of stable forest. After the first period 1985/1995, the deforestation caused by the expansion of this activity occurred mostly in secondary succession (SS) areas. These results (Table 1.12) shown that there is a decreasing trend in the pressure of Eucalyptus plantations over forest remnants in the Paraíba Valley, yet it remains relevant to areas in secondary succession, SSA and SSB.

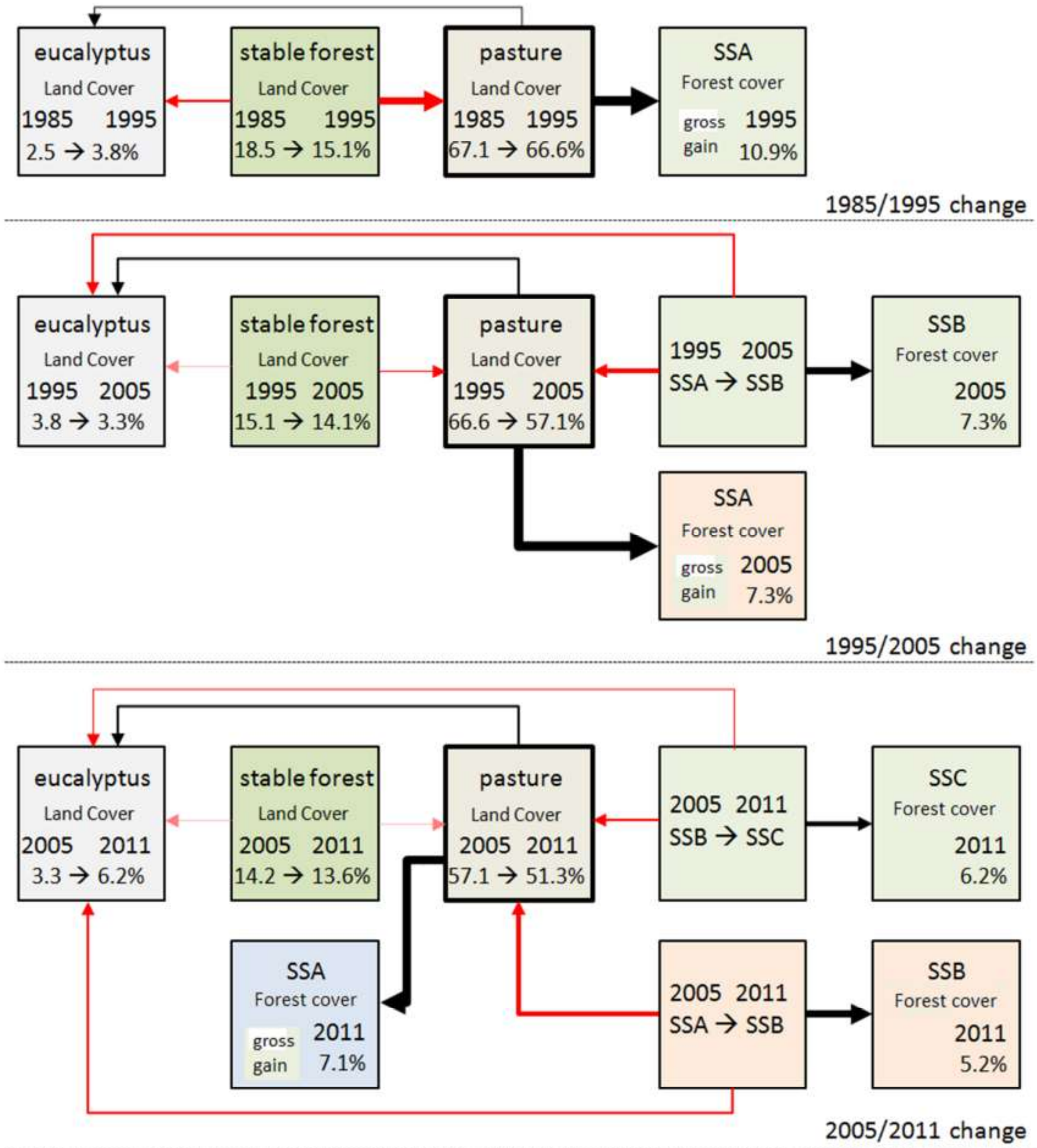

Figure 1.8. The temporal analysis for the Paraíba Valley landscapes shows a consistent trend in the forest cover increase. The pasture class is highlighted as it represents the landscape matrix. The red arrows represent deforestation and the black arrows the rates of forest cover net gain (SS). The different arrow thickness represents the contribution of each class for the change trajectories.

Table 1.12. The data represent the total percentage (100%) of deforestation rates caused by Eucalypts for each period of analysis.

	Deforestation over the sub-class of (%)		
Years	SSA	SSB	Stable forest
1985/1995			100
1995/2005	74		25
2005/2011	58	27	13

5. Discussion

5.1 LULC Mapping

In order to address the questions raised in the introduction (*a*) the proposed multistage classification technique presented kappa coefficients with the best performance for all years in comparison to the single-stage methods. Significant statistic differences between kappa coefficients were observed for some of the classification tests (Table 1.6). Therefore, the multistage approach presented a significant contribution for accuracy improvements in LULC classifications, especially to separate Eucalyptus plantation from forest and other vegetation covers with acceptable accuracy, using medium spatial resolution images (TM), and pixel-based classification procedures. Thus, the Improved Normalized Difference Built-up Index presents an approach to classify Eucalyptus plantation. Finally, it provides a valuable tool to improve the classification of planted forests in a monoculture system, previously mapped mainly by visual image interpretation or unsupervised classifications (Souza et al. 2007; Arguello et al. 2010; Leite et al. 2012; Veloso and Rosa 2012; Leite et al. 2013).

(*b*) This article explored the spectral relationship between LULC classes in a TM/Landsat-5 time series for the purposes of multitemporal classifications, accuracy assessment and change analysis in Atlantic forest transitional landscapes. Ancillary maps generated from the 2011 reference library using the Spectral Angle Mapper classifier had a supporting role in the collection of training data for the classification procedures. The hypothesis tests, aiming to evaluate the compatibility between the training data for 1985, 1995, and 2005 with 2011 (spectral library – reference data), from the reflectance values of the LULC classes in the 6 bands (1, 2, 3, 4, 5, 7 TM/Landsat-5), indicated that the training data were suitable for the supervised classification algorithms.

This paper is a step-forward in the multitemporal classification approaches since it provides a reliable test to measure the confidence level of the training samples in the time series by the two-tailed hypothesis test. Taking into account the challenges behind LULC classifications in specific dates where there are few or any ancillary information, the procedures explored to develop the training data for dates prior to 2011 (reference data) contributed to these advances of multitemporal LULC classification. This statement is possible because the results from spectral analysis infer that the land use classes is consistent with expected spectral behavior, expressed through constant reflectance values in the time series, and statically significant at the 1% significance level.

(*c*) The proposed change detection method provided a dynamic view of changes in the transitional landscape of the Paraíba Valley, providing information about the forest stability and the rates of deforestation and forest cover net gain. Several regions have showed the expansion and recovery of forest cover over areas where there was land abandonment, a land trajectory related to social, economic and political changes (Lambin and Meyfroidt 2009; Farinaci and Batistella 2012; Prishchepov et al. 2012). In the Paraíba Valley, where 74% of the forest cover net gain between 1985 and 2011 occurred over areas of degraded pasture in 1985, indicates that the land use abandonment and consequent forest regeneration is a phenomenon observed on this study region and should be considered the main trajectory of change to explain the positive rates of forest cover increase.

The change detection results addressed the needs pointed out by Farinaci and Batistella (2012) in that it identified the pathways followed by the forest cover increase and, the deforestation patterns, revealing the spatiotemporal relation between the Atlantic forest remnants, its new patches and the other land uses.

5.2 LULC change: Implications for the Atlantic Forest transional landscapes of the Paraíba Valley

Over the past 50 years, the Paraíba Valley has undergone a major socioeconomic transition, from being primarily characterized by agricultural production to one characterized by an industrialized economy, with important contributions to the Gross Domestic Product (GDP) of Sao Paulo State (Boffi et al. 2006; Itani et al. 2011; Vieira and Santos 2012). The rural population, which in 1950 was 55% of the total decreased to 5.3% in 2010, and the outmigration process was driven to industrialized municipalities in the region (Vieira and Santos 2012). Research in other regions of the world have identified industrial and economic development, and population dynamics as important underlying drivers for LULC changes (Foster et al. 1998; Mather et al. 1999; Meyfroidt and Lambin 2009) and forest transitions (Rudel et al. 2010; Redo et al. 2012).

Forest recovery may also have been favored by the establishment of protected areas established since 1971, the legal protection of the Atlantic Forest biome in 1990 by the Federal Decree n^{0} 99.547 that regulates the article 225 of the Brazilian Federal Constitution of 1988. Public conservation policies for the Atlantic Forest biome represent important institutional frameworks for the control of deforestation (Lima and Capobianco 1997), which in recent decades has played an important role in the control of deforestation in forest remnants established in the Paraíba Valley since 1985. This effect has potential for biodiversity conservation and for the process of forest recovery, (Lira et al. 2012).

The Paraíba Valley pasturelands, around 67% of the total area in 1985, decreased to 51% by 2011. The number of cattle in the Paraíba Valley changed from 434053 in 1985 to 669667 (animal unit) in 2011 (Municipal Cattle Survey, years 1985 and 2011 <http://www.sidra.ibge.gov.br/bda/pesquisas/ppm/default.asp>). The data indicates that the stocking rate increased from 0.4 to 0.9 AU/ha (animal unit/hectare). Considering only the managed pasture class (Table 1.2), the stocking rate changed from 1.07 to 1.66 AU/ha. In the second case, the Paraíba Valley has reached the capacity limit (1.5 AU/ha) for an extensive grazing system (Veiga 2005). For the next few years if this trend does not change, the results will be: overgrazing with consequent decay in productivity and degradation of pasturelands, or agricultural intensification, both with potential effects on forest and land changes. For the first case, overgrazing will lead the Atlantic Forest in Paraíba Valley to new cycles of deforestation or pressure over the sucessional vegetation impacting the process of forest recovery. In the second case, the intensification has the potential to promote changes, raising the productivity of the pasturelands and reducing the needs of new lands for cattle, and so, contributing to the return of forest covered areas. According to Grau and Aide (2008), the potential switch from production in traditional extensive grazing areas to intensive modern agriculture provides opportunities to significantly increase food production while sparing land for nature conservation.

Previous research in the Atlantic Forest biome had identified a progressive predominance of secondary forests compared to mature forests, thereby calling attention to a decrease in the capacity of this biome to provide a home to the most sensitive species (Teixeira et al., 2009). In the Paraíba Valley landscape 14.72% of forest cover in 2005 was secondary succession, and 14.07% mature forest (stable forest subclass); tendency accentuated in 2011, when 18.57% of forest cover was secondary succession, and 13.61% mature forest. Despite of the fact that secondary forests may not ensure home to the most sensitive species, Lira et al. (2012) has been highlighted the increase of sencodary forest areas as important for biodiversity conservation in the biome due to the potential effect of young secondary forests in reducing the isolation of forest remnants and maintaining significant amounts of original biodiversity

6. Conclusions

From the perspective of remote sensing, the hypothesis test is a promising method to analyze the validity of the training samples for multitemporal studies where there is a reference dataset, in the case study, the spectral library, year of 2011. The land use classes have expected spectral behavior expressed through constant reflectance values in the time series, essential information to explore multitemporal classifications through spectral analysis. Even with good results for the mapping of LULC distribution by the single-stage methods of ML and NN, the multistage technique performed better. Considering the importance of the quality in the classification results for change detection by post-classification methods, the proposed multistage technique brought an important contribution to the multitemporal study of the forest landscape in the Paraíba Valley, and for future studies focusing in classification procedures aiming at differentiating between natural forest and monoculture forest plantations.

The analysis of changes in the forest cover in this paper has concluded that, the deforestation rates tend to decrease and tend to concentrate mainly on early stages of secondary succession (SSA). This result indicates pressure reduction exerted by deforestation over mature forests and on advanced stages of forest recovery. The highest contribution of deforestation led by Eucalyptus plantations was in 2005/2011; however, 86.7% of this contribution was concentrated in secondary successional areas. This result indicates a tendency to stabilize the relationship between Eucalyptus plantations and Atlantic forest remnants. The Paraíba Valley seems to be undergoing a process of landscape changes where the gains of new areas of forest overcome losses from deforestation, e.g., experiencing a forest transition (Rudel et al. 2010). This process is still new and requires further studies and long-term monitoring, to assess the stability of this process over time. The dynamics of LULC showed that degraded pasture areas considered as land use abandonment are important to the forest recovery dynamics. This phenomenon suggests that the underlying causes of changes, such as the effect of public policy, socioeconomic and cultural changes, have played a fundamental role in the land change trajectories, and have resulted in forest cover net gain.

References

Abraf. 2013. *Anuário Estatístico ABRAF 2013* [Statistical Yearbook ABRAF 2013]. Brasília: ABRAF. http://www.bibliotecaflorestal.ufv.br/handle/123456789/3910.

Almeida, A. Q., A. Ribeiro, and F. P. Leite. 2013. "The water balance in watershed with commercial plantation of *Eucalyptus grandis x urophylla* in eastern Minas Gerais, Brazil." *Revista Árvore* 37(3): 547-556. doi. 10.1590/S0100-67622013000300018.

Arguello, F. V. P., G. T. Batista, F. J. Ponzoni, and N. W. Dias. 2010. "Spatial Distribution of Eucalyptus plantations in the São Paulo State portion of Paraíba do Sul river basin, Brazil." *Revista Ambiente e Água* 5(3): 133-146. doi. 10.4136/1980-993X.

Batistella, M., and E. F. Moran. 2005. "Human dimensions of land use and land cover in the Amazon: a contribution from LBA." *Acta Amazonica* 35(2): 239-247. doi. 10.1590/S0044-59672005000200014.

Baumann, M., M. Ozdogan, T. Kuemmerle, K. J. Wendland, E. Esipova, and V. C. Radeloff. 2012. "Using the Landsat record to detect forest-cover changes during and after the collapse of the Soviet Union in the temperate zone of European Russia." *Remote Sensing of Environment* 124: 174-184. doi. 10.1016/j.rse.2012.05.001.

Boffi, S. A. N. O., F. Ricci, and E. A. A. Q. Oliveira. 2006. "Historical Analysis of the Paraíba Valley region as an attractive place to the industry (1930 – 1980)." [Análise histórica da região do Vale do Paraíba como atrativo para a implantação da indústria de base (1930 - 1980)] *Revista Univap* 13(24): 3059-3063. http://www.inicepg.univap.br/cd/INIC_2006/epg/06/EPG00000542_ok.pdf.

Borges, L. F. R., J. R. Scolforo, A. D. Oliveira, J. M. Mello, F. W. Acerbi, and G. D. Freitas. 2004. "Inventory of Native Forest Fragments and Proposals for their Landscape Management." *Cerne* 10: 22-38. http://www.dcf.ufla.br/cerne/artigos/11-02-20096334v10_n1_artigo%2003.pdf.

Bruzzone, L., P. C. Smits, and J. C. Tilton. 2003. "Foreword Special Issue on Analysis of Multitemporal Remote Sensing Images." *IEEE Transactions on Geoscience and Remote Sensing* 41(11): 2419-2422. doi. 10.1109/TGRS.2003.820004.

Bruzzone, L., and R. Cossu. 2002. "A Multiple-Cascade-Classifier System for a Robust and Partially Unsupervised Updating of Land-Cover Maps." *IEEE Transactions on Geoscience and Remote Sensing* 40(9): 1984-1996. doi. 10.1109/TGRS.2002.803794.

Chavez, P. S. 1988. "An improved dark-object subtraction technique for atmospheric scattering correction of multispectral data." *Remote Sensing of Environment* 24: 459-479. doi. 10.1016/0034-4257(88)90019-3.

Coppin, P. R., I. Jonckheere, K. Nackaerts, B. Muys, and E. F. Lambin. 2004. "Digital change detection methods in ecosystem monitoring: a review." *International Journal of Remote Sensing* 25(9): 1565-1596. doi. 10.1080/0143116031000101675.

Corte, A. P. D., F. L. Dlugosz, and J. A. S. Centeno. 2008. "Image Segmentation of SPOT-5 satellite tests applied to manmade forest." *Revista Acadêmica de Ciência Agrária e Ambiental* 6(2): 249-257. http://www2.pucpr.br/reol/index.php/ACADEMICA?dd1=2400&dd99=view.

Datt, B. 1999. “Remote sensing of water content in *Eucalyptus* leaves.” *Australian Journal of Botany* 47: 909-923. doi. 10.1071/BT98042.

Ditt, E. H., S. Mourato, and J. Ghazoul. 2010. “Forest conversion and provision of ecosystem services in the Brazilian Atlantic Forest.” *Land Degradation & Development* 21(6): 591-603. doi. 10.1002/ldr.1010.

Du, P., J. Xia, W. Zhang, K. Tan, Y. Liu, and S. Liu. 2012. “Multiple Classifier system for Remote Sensing Image Classification: A Review.” *Sensors* 12(4): 4764-4792. doi. 10.3390/s120404764.

El-Magd, I. B., and T. W. Tanton. 2003. “Improvements in land use mapping for irrigated agriculture from satellite sensor data using a multi-stage maximum likelihood classification”. *International Journal of Remote Sensing* 24(21): 4197–4206. doi. 10.1080/0143116031000139791.

Espírito-Santo, F. D. B., Y. E. Shimabukuro, J. R. Santos, and T. M. Kuplich. 2005. “Semi-automatic Multitemporal Image Classification to determine sucessional stages of a deforested area in Amazon.” [Classificação semi-automática de imagens multitemporais Landsat para a determinação dos estágios sucessionais de uma área de desflorestamento na Amazônia]. Paper presented at the XII meeting for the Brazilian Society of Remote Sensing, Goiânia, April 1517-1524.

Farinaci, J. S., L. C. Ferreira, and M. Batistella. 2013. “Forest transition and ecological modernization: eucalyptus forestry beyond good and bad.” *Ambiente e Sociedade* XVI: 25-44. doi. 10.1590/S1414-753X2013000200003.

Farinaci, J. S., and M. Batistella. 2012. “Variation on native vegetation cover in São Paulo: an overview of current knowledge.” *Revista Árvore* 36(4): 695-705. doi. 10.1590/S0100-67622012000400011.

Farinaci, J. S. 2012. “The new Forests in São Paulo State: a multiscalcar study under the perspective of the Forest Transition Theory.” PhD diss., University of Campinas.

Foley, J. A., R. Defries, G. P. Asner, C. Barford, G. Bonan, S. R. Carpenter, F. S. Chapin, M. T. Coe, G. C. Daily, H. K. Gibbs, J. H. Helkowski, T. Holloway, E. A. Howard, C. J. Kuvharik, C. Monfreda, J. A. Patz, I. C. Prentice, N. Ramankutty, and P. K. Snyder. 2005. "Global consequences of land use." *Science* 309(5734): 570-574. doi. 10.1126/science.1111772.

Foody, G. M. 2004. "Thematic Map Comparison: Evaluating the statistical significance of differences in classifications accuracy." *Photogrammetric Engineering & Remote Sensing* 70(5): 627-633. doi. 10.14358/PERS.70.5.627.

Foody, G. M. 2002. "Status of Land Cover Classification Accuracy Assessment". *Remote Sensing of Environment* 80 (1): 185–201. doi. 10.1016/S0034-4257(01)00295-4.

Foody, G. M., D. S. Boyd, and C. Sanchez-Hernandez. 2007. "Mapping a specific class with an ensemble of classifiers." *International Journal of Remote Sensing* 28(8): 1733–1746. doi. 10.1080/01431160600962566.

Foster, D. R., G. Motzkin, and B. Slater. 1998. "Land-use history as long-term broad-scale disturbance: regional forest dynamics in Central New England." *Ecosystems* 1: 96–119. doi. 10.1007/s100219900008.

Freitas Junior, G., A. A. Marson, and D. A. G. Solera. 2012. "The Eucalyptus in the Paraíba Valley: historic and geographic aspects." [Os eucaliptos no Vale do Paraíba paulista: aspectos geográficos e históricos]. *Revista Geonorte* 1(4): 221 – 237.

Freitas, S. R., T. J. Hawbaker, and J. P. Metzger. 2010. "Effects of roads, topography, and land use on forest dynamics in the Brazilian Atlantic Forest." *Forest Ecology and Management* 259(3): 410-417. doi. 10.1016/j.foreco.2009.10.036.

Funcate. 2012. *Emissões do setor de uso da terra, mudanças do uso da terra e florestas: relatório de referência/FUNCATE, CETESB* [GHG Emissions from Land Use, Land-Use Change, and Forestry Sector in São Paulo State]. São Paulo: CETESB. http://www.cetesb.sp.gov.br/inventario-gee-sp/inventario-esp/287-ghg-emissions-from-land-use--land-use-change--and-forestry-sector-in-sao-paulo-state.

Fundação SOS Mata Atlântica/INPE. 2012. *Atlas dos remanescentes de Mata Atlântica período 2011-2012* [Atlas of the Atlantic forest remnants in the period of 2011-2012]. São Paulo: Fundação SOS Mata Atlântica/INPE. http://www.sosma.org.br/link/atlas2011-12/ATLAS_apresentacao_2011_2012_COLETIVA.pdf.

Grau, H. R., and M. Aide, 2008. "Globalization and Land-Use Transitions in Latin America". *Ecology and society*. 13(2): 16. http://www.ecologyandsociety.org/vol13/iss2/art16/.

Hasperger, A. M., M. P. Gennaio, P. H. Verburg, and M. Bürgi. 2010. "Linking land change with driving forces and actors: four conceptual models." *Ecology and Society* 15(4): 1. http://www.ecologyandsociety.org/vol15/iss4/art1/.

He, C., P. Shi, D. Xie, and Y. Zhao. 2010. "Improving the normalized difference built-up index to map urban built-up areas using a semiautomatic segmentation approach." *Remote Sensing Letters* 1(4): 213-221. doi. 10.1080/01431161.2010.481681.

Hill, J., and B. Sturm. 2007. "Radiometric correction of multitemporal Thematic Mapper data for use in agricultural land-cover classification and vegetation monitoring." *International Journal of Remote Sensing* 12(7): 1471-1491. doi. 10.1080/01431169108955184.

Hudson, W. D., and C. W. Ramm. 1987. "Correct formulation of Kappa coefficient of agreement." *Photogrammetric Engineering and Remote Sensing* 53(4): 421-422. http://info.asprs.org/publications/pers/96journal/april/1996_apr_401-402.pdf.

IF – Instituto Florestal. 2005. *Inventário Florestal da Vegetação Natural do Estado de São Paulo* [Forest Inventory of the Natural Vegetation of São Paulo State]. São Paulo: SMA/IF.

Itani, M. R., C. M. Barros, F. E. L. Figueiredo, M. R. M. Andrade, M. T. C. Mansor, R. L. Mangabeira, and V. S. Carvalho, ed. 2011. *Subsídios ao planejamento ambiental: Unidade de Gerenciamento de Recursos hídricos Paraíba do Sul – UGRHI 02* [Subsidies for Environmental Planning: Hydrographic Unit Water of Resources Management of Paraíba do Sul – UGRHI 02]. São Paulo: SMA. http://www.ambiente.sp.gov.br/wp/cpla/files/2011/05/Subsidios_ao_Planejamento_Ambiental_UGRHI-021.pdf.

Key, T., T. A. Warner, J. B. McGraw, and M. A. Fajvan. 2001. "A Comparison of Multispectral and Multitemporal Information in High Spatial Resolution Imagery for Classification of Individual Tree Species in a Temperate Hardwood Forest." *Remote Sensing of Environment* 75(1): 100– 112. doi. 10.1016/S0034-4257(00)00159-0.

Kröger, M. 2012. Global tree plantation expansion: a review. *ICAS Review Paper Series* 3: 1-24. https://helda.helsinki.fi/bitstream/handle/10138/39217/Markus_Kroeger_ICAS_WP_3_EN.pdf?sequence%20=%202.

Lambin, E. F., and P. Meyfroidt. 2009. "Land use transitions: Socio-ecological feedback *versus* socio-economic change." *Land Use Policy* 27(2): 108-118. doi. 10.1016/j.landusepol.2009.09.003.

Lasanta, T., and S. M. Vicente-Serrano. 2012. "Complex land cover change processes in semiarid Mediterranean regions: An approach using Landsat images in northeast Spain." *Remote Sensing of Environment* 124: 1– 14. doi. 10.1016/j.rse.2012.04.023.

Leão, R. O. M. 2005. "Regressive Evolution of stream channels by sub-surface water flow: geo-hydro-ecological bases for recovering degraded areas by the controlling of erosion." PhD diss., Federal University of Rio de Janeiro.

Leite, M. E., J. W. L. Almeida, and R. F. Silva. 2012. “Spatial-temporal analysis of eucalyptus in the north of Minas Gerais in the years 1986, 1996 and 2010.” *GeoTextos* 8(2): 59-74. http://www.portalseer.ufba.br/index.php/geotextos/article/viewFile/5931/4645.

Leite, M. E., J. W. L. Almeida, R. Magalhães Filho, and C. M. S. Clemente. 2013. “Mapping of Eucalyptus in the municipalities of the northern region of Minas Gerais with remote sensing data.” [Mapeamento do eucalipto nos municípios da mesorregião Norte de Minas Gerais com o uso de dados de sensoriamento remoto]. Paper presented at the XVI meeting for the Brazilian Society of Remote Sensing, Foz do Iguaçu, April 3238-3244.

Lima, A. R., and J. P. R. Capobianco. 1997. *Mata Atlântica: avanços legais e institucionais para sua conservação* [Atlantic Forest: legal and institutional advances for its conservation]. São Paulo: ISA. http://site-antigo.socioambiental.org/banco_imagens/pdfs/10103.pdf.

Lira, P. K., L. R. Tambosi, R. M. Ewers, and J. P. Metzger. 2012. “Land-use and Land-cover change in Atlantic Forest Landscapes.” *Forest Ecology and Management* 278: 80-89. doi. 10.1016/j.foreco.2012.05.008.

Lu, D., P. Mausel, E. Brondízio, and E. Moran. 2003. “Classification of Successional Forest Stages in the Brazilian Amazon Basin”. *Forest Ecology and Management* 181(3): 301-312. doi. 10.1016/S0378-1127(03)00003-3.

Lu, D., P. Mausel, M. Batistella, and E. Moran. 2005. “Land-cover binary change detection methods for use in the moist tropical region of the Amazon: a comparative study.” *International Journal of Remote Sensing* 26(1): 101-114. doi. 10.1080/01431160410001720748.

Lu, D., and Q. Weng. 2007. “A survey of image classification methods and techniques for improving classification performance.” *International Journal of Remote Sensing* 28(5): 823-870. doi. 10.1080/01431160600746456.

Lu, D., M. Batistella, and E. Moran. 2008. “Integration of Landsat TM and SPOT HRG images for vegetation change detection in the Brazilian Amazon.” *Photogrammetric Engineering and Remote Sensing* 74(4): 421-430. http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2752897/pdf/nihms116348.pdf.

Lu, D., M. Batistella, G. Li, E. Moran, S. Hetrick, C. C. Freitas, L. V. Dutra, and S. J. S. Sant’Anna. 2012. “Land use/cover classification in the Brazilian Amazon using satellite images.” *Pesquisa Agropecuária Brasileira* 47: 1185-1208. doi. 10.1590/S0100-204X2012000900004.

Machado, A. M. B., G. M. Drummond, and A. P. Paglia. 2008. *Livro vermelho da fauna brasileira ameaçada de extinção* [The Red Book of endangered species of Brazilian fauna]. Brasília: MMA/Fundação Biodiversitas. http://www.icmbio.gov.br/portal/biodiversidade/fauna-brasileira/lista-de-especies/livro-vermelho.

Magnago, L. F. S., M. Simonelli, S. V. Martins, F. A. R. Matos, and V. G. Demuner. 2011. “Structural Changes and Edaphic Characteristics in Different Succession Stages of Tabuleiro Riparian Forest, ES.” *Revista Árvore* 35(3): 445-456. Doi. 10.1590/S0100-67622011000300008.

Maire, G., S. Dupuy, Y. Nouvellon, R. A. Loos, and R. Hakamada. 2014. “Mapping short-rotation plantations at regional scale using MODIS time series: Case of eucalypt plantations in Brazil.” *Remote Sensing of Environment* 152: 136-149. doi. 10.1016/j.rse.2014.05.015.

Mather, A. S., J. Fairbairn, and C. L. Needle. 1999. “The course and drivers of the forest transition: the case of France.” *Journal of Rural Studies* 15(1): 65–90. doi. 10.1016/S0743-0167(98)00023-0.

Mazzolli, M. 2010. “Mosaics of Exotic Forest Plantations and Native Forests as Habitat of Pumas.” *Environmental Management* 46(2): 237-253. doi. 10.1007/s00267-010-9528-9.

Mello, T. F. 2009. "Vegetation structure, forest cover, and land use preferences in the landscape associated with aspects of topography: the almost forests of São Luiz do Paraitinga (SP)." PhD diss., University of São Paulo.

Moran, E. F., and E. Ostrom, ed. 2005. *Seeing the Forest and the Trees: Human-Environment Interactions in Forest Ecosystems*. Cambridge: MIT Press.

Mountrakis, G., J. Im, and C. Ogole. 2011. "Support Vector Machines in remote sensing: A review." *Journal of Photogrammetry and Remote Sensing* 66(3): 247-259. doi. 10.1016/j.isprsjprs.2010.11.001.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. Fonseca, and J. Kent. 2000. "Biodiversity hotspots for conservation priorities." *Nature* 403(1): 852-858. doi. 10.1038/35002501.

Neves, O. M. S., F. Carriello, and D. A. Rodriguez. 2013. "The expansion of Eucalyptus plantation in the Paraíba Valley between 1995 and 2010, and its relation with hydrologic features of the watershed." [A expansão da cultura de eucalipto na região do Vale do Paraíba entre 1995 e 2010 e sua relação com as características hidrológicas da bacia]. Paper presented at the XVI meeting for the Brazilian Society of Remote Sensing, Foz do Iguaçu, April 7608-7615.

Paula, M. D., C. P. A. Costa, and M. Tabarelli. 2011. "Carbon storage in a fragmented landscape of Atlantic forest: the role played by edge-affected habitats and emergent trees." *Tropical Conservation Science* 4(3): 349-358. http://tropicalconservationscience.mongabay.com/content/v4/11-09-25_340-349_Dantas_et_al.pdf.

Pillar, V. D. P. 1994. "Temporal Dynamics of Vegetation." [Dinâmica temporal da vegetação]. UFRGS: Departamento de Botânica. Accessed December 5, 2013. http://ecoqua.ecologia.ufrgs.br.

Prishchepov, A. V., V. C. Radeloff, M. Baumann, and T. Kuemmerle. 2012. "Effects of massive socio-economic change on land-use change: Agricultural abandonment during the socio-economic transition in post-Soviet Eastern Europe." *Environmental Research Letters* 7(2): 1-13. doi. 10.1088/1748-9326/7/2/024021.

Roberts, D. A., I. Numata, K. Holmes, G. Batista, T. Krug, A. Monteiro, B. Powell, and O. A. Chadwick. 2002. "Large area mapping of land-cover change in Rondônia using multitemporal spectral mixture analysis and decision tree classifiers." *Journal of Geophysical Research* 107(D20): 40-1-40-20. doi. 10.1029/2001JD000374.

Rudel, T. K., L. Schneider, and M. Uriarte. 2010. "Forest transitions: An introduction." *Land Use Policy* 27(2): 95-97. doi. 10.1016/j.landusepol.2009.09.021.

Sâvulescu, I., and B. Mihai. 2012. "Mapping forest landscape change in Iezer Mountains, Romanian Carpathians. A GIS approach based on cartographic heritage, forestry data and remote sensing imagery." *Journal of Maps* 7: 429-446. doi. 10.4113/jom.2011.1170.

Sell, J. K., and A. S. Figueiró. 2011. "Transformation of the landscape and social and environmental impacts on Pampa Biome." *Revista da ANPEGE* 7(8): 129-141. doi. 10.5418/RA2011.0708.0010.

Serra, P., X. Pons, and D. Sauri. 2003. "Post-classification change detection with data from different sensors: some accuracy considerations." *International Journal of Remote Sensing* 24(16): 3311–3340. doi. 10.1080/0143116021000021189.

Shafri, H. Z. M., A. Suhaili, and S. Mansor. 2007. "The Performance of Maximum Likelihood, Spectral Angle Mapper, Neural Network and Decision Tree Classifiers in Hyperspectral Image Analysis." *Journal of Computer Science* 3(6): 419-423. doi. 10.3844/jcssp.2007.419.423.

Silvano, R. A. M., S. Udvardy, M. Ceroni, and J. Farley. 2005. "An ecological integrity assessment of a Brazilian Atlantic Forest watershed based on surveys of stream health and local farmers' perceptions: implications for management." *Ecological Economics* 53(3): 369-385. doi. 10.1016/j.ecolecon.2004.12.003.

Silveira, P. C. B. 2009. “Hybrids from landscape: ethnography of production and conservation spaces.” *Ambiente e Sociedade* 12(1): 83-98. Doi. 10.1590/S1414-753X2009000100007.

Soares, V. P., W. D. Guimarães, C. A. A. S. Ribeiro, and A. S. Silva. 2005. “Use of orbital images for mapping Eucalyptus forest plantations in the north region of Minas Gerais state, Brazil.” *Floresta* 35(1): 137-149. doi. 10.5380/rf.v35i1.2437.

Souza, C. C., A. A. Moreira, R. S. Schimith, P. C. Brandão, and E. Silva. 2007. “Remote Sensing techniques to subsidize studies about planted forests in Brazil – a review.” [Técnicas de sensoriamento remoto como subsídios aos estudos de florestas implantadas no Brasil – uma revisão bibliográfica]. *Ciência Florestal* 17(4): 409-417. doi. 10.5902/19805098.

Stasi, L. C. D., G. P. Oliveira, M. A. Carvalhaes, M. Queiroz-Junior, O. S. Tien, S. H. Kakinami, and M. S. Reis. 2002. “Medicinal plants popularly used in the Brazilian Tropical Atlantic Forest.” *Fitoterapia* 73(1): 69-91. doi. 10.1016/S0367-326X(01)00362-8.

Teixeira, A. M. G., B. S. Soares-Filho, S. R. Freitas, and J. P. Metzger. 2009. “Modeling landscape dynamics in an Atlantic Rainforest region: Implications for conservation.” *Forest Ecology and Management* 257(4): 1219-1230. doi. 10.1016/j.foreco.2008.10.011.

Tilman, D. 1999. “Global environmental impacts of agricultural expansion: the need for sustainable and efficient practices.” *Proceedings of the National Academy of Sciences of the United States of America* 96(11): 5995–6000. doi. 10.1073/pnas.96.11.5995.

Vaca, R. A., D. J. Golicher, L. Cayuela, J. Hewson, and M. Steininger. 2012. “Evidence of Incipient Forest Transition in Southern Mexico.” *PLoS ONE* 7(8): e42309. doi. 10.1371/journal.pone.0042309.

Veiga, J. B. 2005. *Criação de gado leiteiro na Zona Bragantina* [Dairy cattle production at the Bragantina Zone]. Belém: Embrapa Amazônia Oriental (Sistemas de Produção,

n^{0}2).
http://sistemasdeproducao.cnptia.embrapa.br/FontesHTML/Leite/GadoLeiteiroZonaBragantina/index.htm.

Veloso, G. A., and R. Rosa. 2012. “Mapping of Eucalyptus plantation in the micro-region of Salinas, North Minas Gerais, in the years of 1986, 1996, and 2010.” [Mapeamento da monocultura do eucalipto na microrregião de Salinas, Norte de Minas Gerais, nos anos de 1986, 1996 e 2010]. Paper presented at the XXI national meeting for the Society of Geographic and Agrarian studies, Uberlândia, October 1-12.

Vieira, E. T., and M. J. Santos. 2012. “Industrialization and regional development: policies in Paraíba Valley in the 70’S.” *Desenvolvimento Regional em debate* 2(2): 161-181. http://www.periodicos.unc.br/index.php/drd/article/view/265/296.

Villela, D. M., E. A. Mattos, A. S. Pinto, S. A. Vieira, and L. A. Martinelli. 2012. “Carbon and nitrogen stock and fluxes in coastal Atlantic Forest of southeast Brazil: potential impacts of climate change on biogeochemical functioning.” *Brazilian Journal of Biology* 72(3): 633-642. doi. 10.1590/S1519-69842012000400003.

Whitehead, D., and C. L. Beadle. 2004. “Physiological regulation of productivity and water use in Eucalyptus: a review.” *Forest Ecology and Management* 193: 113-140. doi. 10.1016/j.foreco.2004.01.026.

Wilson, G. A. 2008. “From ‘weak’ to ‘strong’ multifunctionality: Conceptualising farm-level multifunctional transitional pathways.” *Journal of Rural Studies* 24: 367–383. doi. 10.1016/j.jrurstud.2007.12.010.

Capítulo II

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Drivers of Land Change: Human-Environment Interactions and Atlantic Forest Transition in the Paraíba Valley, Brazil

Abstract: Human societies constantly interact with the environment through mutual feedbacks and adaptations. The aim of this research was to identify and analyze human and environmental dimensions to understand how the dynamic processes of land use change are contributing to the increase of forest cover observed between 1985 and 2011 in the Paraiba Valley, Brazil. The forestry industry, based on eucalyptus plantations, is given particular attention due to its role in these change processes. Logistic regressions (LR) and Multi-layer perception neural network (MPNN) models were adopted to evaluate the influence of independent variables for the process of forest transition. Based on the model´s results, the process is conditioned by a set of biophysical and socioeconomic variables that operate during different historical periods and landscape settings. The proximity of Atlantic forest remnants was an influential variable in the forest transition for the three periods analyzed: 1985 to 1995, 1995 to 2005, and 2005 to 2011. In the first period of change (1985 to 1995), topography was most influential. Between the periods of 1995/2005 and 2005/2011, the proximity to eucalyptus plantations was an important factor, indicating high probability of native forest recovery occurring in the vicinity of these monocultural areas. Forest transition tends to occur in areas less suitable for agriculture but as these areas are replaced by forest cover, socioeconomic driving forces such as farm credit and economic development play important roles in the dynamics of forest regrowth and restoration.

Key words: land use change models; multi-layer perception neural network; logistic regression; forest transition in Brazil.

1. Introduction

Land use and land cover changes (LULCC) are key factors in environmental changes operating at global and regional scales, with impacts on biodiversity, ecosystems services, and climate regulation. An interdisciplinary scientific community was formed in the last two decades to develop research methods capable of dealing with this complex global phenomenon (Moran and Ostrom, 2005). There is great space and time variability in the biophysical environments, socioeconomic activities and cultural contexts associated to land use changes (Lambin et al., 2003).

Driving forces refers to factors affecting change trajectories, observed through time at a particular location. Bürgi et al. (2004) made an attempt to organize the literature about drivers of land change and grouped them in five categories: socioeconomic, political, technological, cultural and natural. These studies aim to establish relations among proximate and underlying causes of LULCC (Ye et al., 2001; Lambin et al., 2001; Prishchepov et al., 2013). Proximate causes represent activities or immediate human actions originating from specific interests on land use promoting land cover changes, while underlying causes such as demographic, social, cultural, political, technological, and biophysical, constitute the initial conditions in human relations with environment, and are systemic in nature (Lambin et al., 2003; Brondízio, 2009).

In Europe, research has shown the effects of political, economic and cultural changes experienced since World War II in natural and cultural landscapes (Bieling et al., 2013; Beilin et al., 2014). In many parts of Eastern Europe, changes in forest cover were observed after the collapse of the Soviet Union, with transition periods marked by deforestation and followed by gradual increases in forest cover in the following decades (Baumann et al, 2012; Griffiths et al., 2012). In an analysis of a period of 224 years (1782-2006) in Slovakia, land use changes were attributed to driving forces related to the different political regimes in history, highlighting the importance of public policies for land use, demographic dynamics, technology and biophysical factors, with notable effects on the increase of agricultural areas, forest transitions and land abandonment (Kanianska et al., 2014).

Land use abandonment motivated by economic and social drivers such as cultural changes, aging of rural population and hardening of policies for agricultural landscape management or environmental conservation, is land cover trajectory for the forest transition, and has impacts on biodiversity, ecosystem regeneration and to setting new landscape functions (Rudel et al., 2005; Meyfroidt and Lambin, 2010; Prishchepov et al., 2013; Beilin et al., 2014).

Forest transition (Rudel et al., 2005; Rudel et al., 2010), a phenomenon first observed in countries of Europe and North America with roots in the process of industrialization and consequent socioeconomic transformations (Foster et al., 1998; Mather et al., 1999; Evans et al., 2005) has been observed more recently in tropical countries (Hecht et al., 2006; Baptista, 2008; Sanchez-Cuervo et al., 2012). According to Lambin and Meyfroidt (2010), even though the patterns of changes in forest cover in these regions are similar, forest transition process are not the same. In Colombia, land abandonment in the past few decades has been partly motivated by the armed conflict and the erradication of coca plantations that has led some regions to have significant rates of native vegetation recovery, while there is greater deforestation in areas of mineral and fossil fuels exploitation, and agricultural expansion in areas free of armed conflict (Sánchez-Cuervo et al., 2012). In Brazil, the national rates of forest loss still outweigh gains in recovery (FAO, 2011) however, the reverse has been observed at regional scales (Baptista, 2008; Farinaci, 2012). Deforestation rates at the national level can conceal significant variations in the rates and patterns of forest changes at local to regional scales (Tucker and Southworth, 2009).

Considering land use and land cover changes as a result of proximate and underlying causes (Geist and Lambin, 2002), this study aims to *(a)* identify the main drivers of forest transition in a region of Brazil and *(b)* understand the importance of eucalyptus forest plantations for this process in the Paraíba Valley, Brazil, between 1985 and 2011.

2. Brazil, Atlantic Forest and Paraíba Valley through temporal and spatial scales

The replacement of natural ecosystems by production systems, based on monoculture cropping or livestock expansion, was primarily responsible for the deforestation of the Atlantic Forest Biome (Teixeira et al., 2009; Rodrigues and Gandolfi, 2007). Currently, forest remnants of this biome comprise around 13% of the original vegetation cover (Fundação SOS Mata Atlântica/INPE, 2012; Ribeiro et al., 2009), and the Atlantic Forest is the Brazilian biome with the highest number of extinct or endangered species. Among the list of species of flora and fauna endangered or extinct, 58% and 63% belong to the Atlantic Forest, respectively (MMA, 2008; Machado et al., 2008).

In 1962, the native forest vegetation, consisting of secondary successional forests and mature forests, comprised 13% in the State of São Paulo and 16% of the Paraíba Valley (Borgonovi et al., 1967). The same study reveals that the Paraíba Valley region was covered by 1% of planted forests (monoculture plantations of *Pinus elliottii* and *Eucalyptus spp*).

Between 1950 and 1980, Brazil experienced an intense process of urbanization and industrialization, a result of import substitution economic policies (Target Plan/*Plano de Metas* in Portuguese), producing changes in the economy, politics and society (Brito, 2006; Alves et al., 2011). In 1950, 64% of the population lived in rural areas (IBGE, 1950). During the Brazilian military regime (1964-1985) modernization of large-scale and export-oriented agriculture was stimulated (Freitas, 2008). The process of industrialization and socioeconomic changes during this period of Brazilian history resulted in a rural exodus, which led the country to a new agricultural economic configuration, and new standards of rural and urban ways of life (Alves et al., 2011).

Between 1959 and 1985, the economic contribution of the Paraíba Valley to the Gross Domestic Product (GDP) of São Paulo State increased from 1.97% to 7.43% (Vieira, 2009). The region's economic development was the result of industrial policies, the construction of President Dutra highway, as well as public and international investments. As an outcome, intense migration fluxes from poorer municipalities to industrial ones took place (Vieira and Santos, 2012). The replacement of agricultural activities by pastures in the 1970s also reduced employment in the rural areas of the Paraíba Valley (Vieira, 2009).

In the 1980s, the Paraíba Valley consolidated its industrial development (Boffi et al., 2006), and its rural population decreased from 55% in 1950 to 5.8% by 2010. Until the 1980s, the protection of the Atlantic Forest biome was restricted by the Brazilian Forest Code, created in 1965. The Brazilian Federal Constitution of 1988 recognized the biome as a national heritage area (art. 225), and in 1990 a Federal Decree (bill 99547), prohibited the harvest and use of natural vegetation for any purpose (Lima and Capobianco, 1997). In 1993, a new policy was approved by the National Environmental Council (CONAMA), which extended the biome protection to the secondary succession formations in the early, middle and advanced stages of regeneration further supporting the restoration of forests.

In 2006 the Atlantic Forest biome became protected by the Federal Law n^0 11428, which regulates the practices of deforestation and condemns transgressions as environmental crimes, according to the Federal Law n^0 9605 of 1998 (Federal Law of Environmental Crimes).

During recent decades, forestry activities in the Paraíba Valley, based on eucalyptus plantations, developed economically and technologically (Itani et al., 2011), and promoting impacts on land use, environment and society (Farinaci, 2012, Silva et al., 2012; Farinaci et al., 2013). This economic sector has its foundations in 1958, when the region hosted its first pulp and paper industry in the city of Jacareí. At the time of the military regime, the "National Plan for Pulp and Paper (1974)" promoted the increase of areas occupied by planted forests and made Brazil a self-sufficient country and eventual exporter of eucalyptus fiber (Barrichello and Queiroz, 2008). The expansion of eucalyptus cultivated areas (Silvestre and Rodrigues, 2007) created tensions between social actors that have benefited from this policy (steel and forestry companies) and those excluded, namely, traditional farming families (Calixto and Ribeiro, 2007).

Currently, eucalyptus in the Paraíba Valley is a commodity dedicated to the production of cellulose pulp traded in international markets. In 2011, 89% of the cellulose pulp production was exported, mainly to Europe and China (Brandão, 2012).

3. Study area

The Paraíba Valley (14500 km^2, Figure 2.1) was one of the first areas occupied in Brazil (Dean, 1996). Far from being of great importance to the colonial economy, it was only in the first half of the XIX century that coffee plantations made their way there and made it a part of this important export crop (Zuquim, 2007; Ricci, 2008; Couto and Serra, 2011). Coffee plantations were responsible for the first deforestation cycle in the Paraíba Valley, declining with the end of slavery. New coffee productive areas in the Central-West region of São Paulo State that developed after the expansion of railways system and land degradation in the Paraiba Valley, resulted in the decline of coffee (Drummond, 1997; Zuquim, 2007). During the XX century, cattle ranching replaced coffee as a major form of land use and maintained the pressure over forest remnants. In the 1980s, while soil and pasture degradation dominated the hilly landscapes (Ferreira et al., 2006; Vieira and Santos, 2012), new economic shifts in

Brazil, namely industrialization, resulted in land abandonment (Vieira, 2009; Itani et al., 2011).

Today, landscapes are dominated by pastures in different stages of degradation, forest remnants, eucalyptus plantations, secondary succession, and urban areas concentrated along the President Dutra highway. Cultural, rural, and ecological tourism linked to the historical past and environmental attractions increased as a rural economic activity in the last decade (Couto and Serra, 2011). Composed by 34 municipalities and accounting for 4.5% of São Paulo state's GDP, the Paraíba Valley lies in the connection axis between the major metropolitan areas of Brazil, e.g., São Paulo and Rio de Janeiro. Due to its steep aand mountainous topography, the region is considered by the Consortium for Integrated Development of Paraíba Valley as unfavorable for the development of large-scale mechanized agriculture. A poorly developed rural road network further contributes to this scenario.

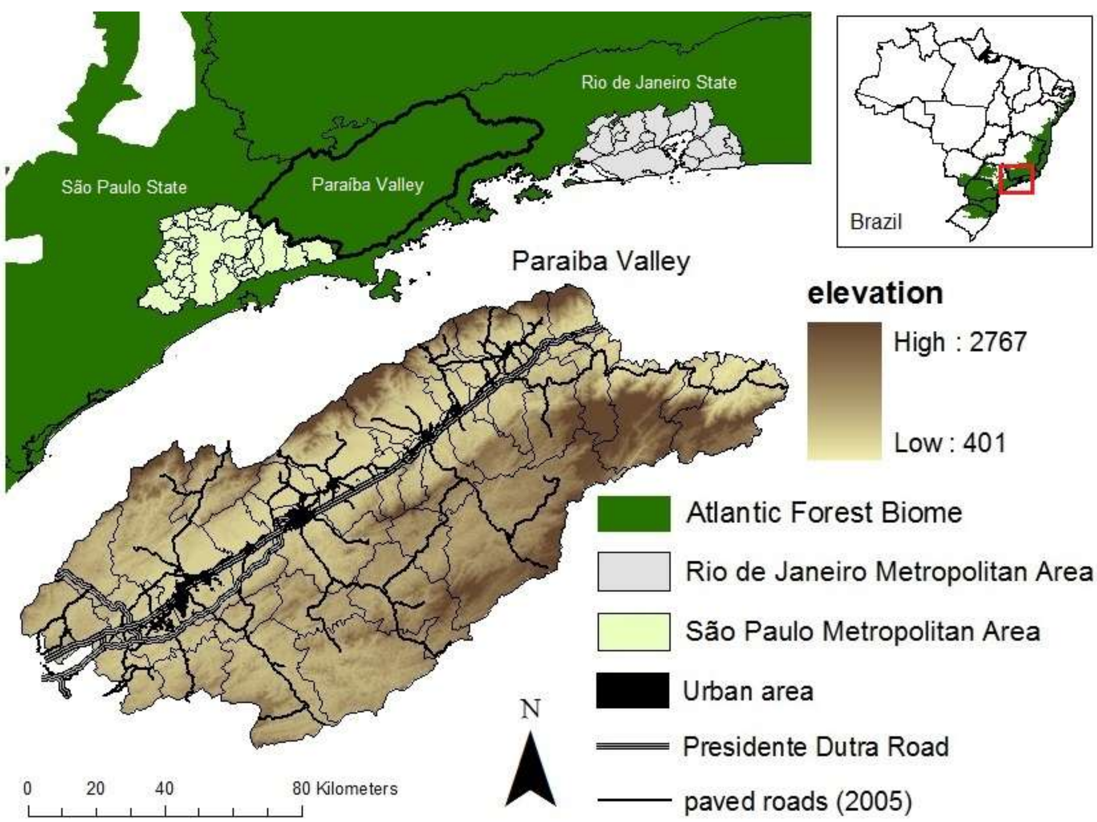

Figure 2.1. Study area: Paraíba Valley, located between the São Paulo and Rio de Janeiro metropolitan areas.

4. Methods

The research was conducted by *(I)* Analysis of land use and land cover changes –1985, 1995, 2005 and 2011. *(ii)* Secondary data collection and analysis. *(iii)* Logistic Regression (LR) and Multi-layer Perception by Neural Network (MLPNN) integrating biophysical and socioeconomic variables. The conceptual framework for this research was based on a Driving Force-Land Change model (DF-C) (Hersperger et al., 2010).

4.1 Land use and land cover mapping and change analysis

A set of Landsat-5 Thematic Mapper (TM) scenes (218/76 and 219/76) was selected, to map land use and land cover change (LULCC) in 1985, 1994, 1995, 2005 and 2011. Image preprocessing included registration and atmospheric correction using the Improved Dark-Object Subtraction (DOS2) method (Chavez, 1988). Based on the review for existing pixel-based classification algorithms (Lu and Weng, 2007), a Maximum Likelihood algorithm (ML) was performed. The TM images (composition 5R4G3B), RapidEye images and field work information were used to define training samples (90%) and test samples (10%) for the supervised classification. Post-classification procedures included majority filters with a window size of 3 by 3 pixels. Mapped classes included:

- *Agriculture:* areas occupied by annual and perennial crops for food, feed and fuel production, e.g. sugar cane, napier grass (*Pennisetum purpureum*), rice, beans and corn.
- *Water:* rivers, lakes and dams.
- *Built-up areas:* urban and peri-urban areas, highways, industrial areas and other built-up areas.
- *Eucalyptus:* monocultural forest plantation with species of the *Eucalyptus* genus.
- *Forest:* vegetation formations including stages of secondary succession (shrubland, young forest) and mature forest.
- *Managed pasture:* areas used for cattle ranching for milk and beef production with a predominance of grasses, e.g. molasses grass and Brachiaria sp.
- *Degraded pasture:* areas with grass cover, presence of shrubs, and other weeds, being used as low productivity pasture or abandoned.

- *Bare soil:* exposed soils associated with agriculture and forestry activities, deforestation or preparation for new built-up areas.

The LULCC analysis was conducted by cross-tabulation matrices, generated from the land use and land cover maps.

4.2 Ancillary data

In environmental research, ancillary data associated to land use and land cover maps are essential to enhance knowledge about the history of a particular region, socioeconomic changes over time, and the outcomes for society and the environment (Hietel et al., 2007; Moran and Ostrom, 2005; Farinaci and Batistella 2012; Beilin et al., 2013; Bieling et al., 2013). The research included internet sites, newspapers, scientific publications, historical documents and socioeconomic statistics. The ancillary data provided a time series of independent variables for the land use models and additional inputs for the discussion about the research results.

4.3 Driving forces of land change

Driving forces represent the independent variables acting in land use change models (Hersperger et al., 2010). These models conceptually assume that the driving forces cause the observed changes, and based on the results, links between driving forces and land changes can be hypothesized. The causal relationship between the driving forces and land use changes are not the primary interest in this case. We are interested in answering more specific questions, such as: i) "What driving forces are more related to the changes?" or ii) "Which driving force contributes more for the change?" Supported by familiarity with the study area and forest transition theory, 17 independent variables were selected for analysis (Table 2.1).

Table 2.1. Independent variables selected to study forest recovering in the Paraíba Valley, São Paulo state, Brazil. Period of 1985 to 1995, 1995 to 2005, and 2005 to 2011.

Variables	Description	Structure	Normalization	Source
X_1	Aspect	continuous	-	ASTER GDEM
X_2	elevation (m)	continuous	-	ASTER GDEM
X_3	rural houses (n^0 of houses)	continuous	square root	IBGE/SEADE[a]
X_4	proximity of eucalyptus (m)	continuous	natural log	Land Use Map
X_5	proximity of forest (m)	continuous	natural log	Land Use Map
X_6	proximity of roads (m)	continuous	natural log	DNIT/MT
X_7	farm job (n^0 of jobs)	continuous	raiz quadrada	MTE/SEADE[a]
X_8	soils (classes)	categorical	evidence likelihood	IA/EMBRAPA[b]
X_9	farm credit ($/ha)	continuous	square root	BACEN/SEADE[a]
X_{10}	formal job (n^0 of jobs)	continuous	square root	MTE/SEADE[a]
X_{11}	Industry and commerce (n^0 of unities)	continuous	square root	SE/SEADE[a]
X_{12}	stocking rate (animal unit/ha)	continuous	square root	IBGE[c]
X_{13}	milk productivity (L/n^0 of animals)	continuous	square root	IBGE[c]
X_{14}	municipal revenue ($)	continuous	square root	MF/SEADE[a]
X_{15}	rural population density (people/ha)	continuous	square root	IBGE/SEADE/SAA[a]
X_{16}	slope (degree)	continuous	-	ASTER GDEM
X_{17}	protected areas	binary	evidence likelihood	MMA[d]

Note: [a]all data for the historical series were generated by public institutes of research and compiled by the State Foundation of Data Analysis System (*SEADE*<https://www.seade.gov.br/> In: “população e estatísticas vitais”).
[b]Oliveira et al., 1999.
[c]Brazilian Institute of Geography and Statistic (IBGE): <http://www.sidra.ibge.gov.br/bda/acervo/acervo2.asp?e=v&p=PP&z=t&o=24>In: “pecuária”.
[d]Brazilian Ministry of Environment: <http://mapas.mma.gov.br/i3geo/datadownload.htm> In: “áreas especiais”.

The variables aspect, elevation and slope were generated from the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model (ASTER GDEM) with horizontal resolution of 1 arcsecond (about 30 meters). The soil map (Oliveira et al., 1999) was organized into five classes according to the Brazilian System of Soil Classification (EMBRAPA, 2006): Ultisols (Argissolos), Inceptisols (Cambissolos), Gleysols (Gleissolos), Oxisols (Latossolos) and Histosols (Organossolos).

The variables of proximity to the forest and eucalyptus were generated from the land use maps of 1985, 1995 and 2005. Binary maps were created for each class (forest and eucalyptus) and distance maps were calculated. The variable proximity to the roads was calculated in relation to paved roads. To build this variable, three road maps for the same years were used. The road maps were created from files supplied by the National Department of Infrastructure and Transport (DNIT). Historical information about roads in Paraíba Valley and about the maps themselves were provided by the National Plan of Logistics and Transport (MT, 2006).

The spatial distribution of the information contained in each socioeconomic variable was performed on the municipal grid vector file, obtained from the website of Brazilian Institute of Geography and Statistics (IBGE <http://www.sidra.ibge.gov.br>), and subsequently transformed to raster format (30 m of spatial resolution). For the variable of rural population density (X_{15}), the total number of rural residents per municipality was divided by the total area occupied by farms within the respective municipality. The information about the total area occupied by farms within each municipality is provided by the "Census of Agricultural Production Units of São Paulo State" project - LUPA (SAA/CATI/IEA, 1995/06; SAA/CATI/IEA, 2007/08). The farm credit variable (X_9) was generated by the sum of total accumulated credit in the period of change divided by the total area occupied by farms within each municipality (SAA/CATI/IEA, 1995/06, SAA/CATI/IEA, 2007/08).

The stocking rate of cattle (X_{12}) was built by dividing the total number of animals in each municipality by the total area occupied as pasturelands in the respective municipality, in the same year (number of animals in 1985/pasturelands in 1985). The other socioeconomic variables are expressed as their real values. For input models, some variables were normalized (Eastman, 2012) (Table 2.1). For each period of change (1985/1995, 1995/2005, 2005/2011), we introduced in the models the independent variables regarding the date of commencement of the period, with the exception of variable X_9.

4.4 Models: logistic regression (LR) and multi-layer perception neural network (MLPNN)

Logistic regression and Multi-layer perception models were used to associate changes of non-forest areas to forest (forest regeneration process) with driving forces (Table 2.1). For this purpose, the land use land cover maps were converted into two classes: forest and non-forest (Figure 2.2). As dependent variable we used the map of change from "non-forest to forest" of each period. The use of two methodological approaches (LR and MLPNN) for the study did not seek to compare methods. We applied both methods to find consistency between the results of the models in order to strengthen the discussion about the influence of driving forces on the forest transition process.

According to Eastman (2012), the Cramer's V test is an exploratory method to define the independent variables to use in a model. This test assesses the capacity or potential (power) of each explanatory variable in relation to the dependent variable. Cramer's V value above 0.15 indicates that the variable have acceptable explanatory power and for this reason, should be maintained in the model, while if a variable have a Cramer's V value below 0.15, it should be excluded of the model (Eastman, 2012). Thus, for each period of change, all variables were tested and only those with values above 0.15 were selected as inputs for the land use change models.

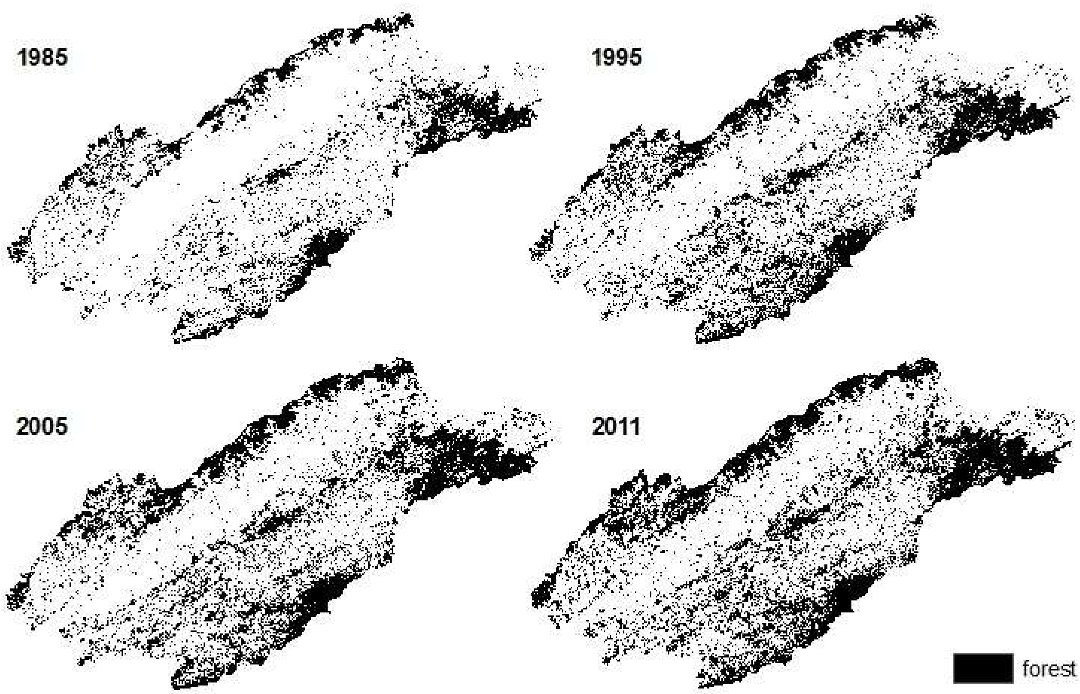

Figure 2.2. Binary maps of forest and non-forest cover classes.

4.5 Logistic regression (LR)

Empirical estimation models use statistical techniques to modeling relationships between land use changes and driving forces based on historical data (Hu and Lo, 2007). As an empirical estimation model, the LR has been used to analyze deforestation (Geoghegan et al., 2001; McConnell et al., 2004; Matricardi et al., 2010), agriculture expansion (Serneels and Lambin, 2001; Ellis et al., 2010) and urban growth (Hu and Lo, 2007; Qingyun and Yu, 2011). For this study we generated a logistic regression for each independent variable (accepted by Cramer's V test) and after a multiple logistic regression with all these variables. To avoid negative effects of spatial autocorrelation, the logistic regressions were performed with a random sample of 10% (Siles, 2009; Arsanjani, 2012). The validity of the logistic regression models was assessed by the results of the relative operating characteristics (ROC). The relative operating characteristic (ROC) assesses the validity of a model that predicts the occurrence of a class by comparing a quantitative image depicting the likelihood of that class occurring with a Boolean image showing where that class actually exists (Eastman, 2012). The value 1 indicates perfect agreement for ROC between two images, while 0.5 means a causal relationship and 0 no agreement (McConnell et al., 2004; Eastman, 2012). For the case study, the results of logistic regression with value 1 to ROC mean perfect agreement between the dependent variable (non-forest to forest) and the driving force.

4.6 Multi-layer perception neural network (MLPNN)

Neural networks facilitate integration between the dynamic interactions of anthropogenic variables with ecological characteristics of the environment (Lippitt et al., 2008). Machine learning methods such as neural networks favor the characterization of models where there are non-linear relationships between the set of variables (Lek and Guegan, 1999). The model MLPNN uses the Back-Propagation algorithm (Rumelhart et al., 1986), which has broad applicability in modeling studies of ecological relationships for predictive or exploratory purposes, especially where the response curves are non-linear (Olden and Jackson, 2001). For the present study, a multi-layer perception was trained by the Back-Propagation (BPN) procedure, which is an artificial neural network with feed-forward using a BPN algorithm (Rumelhart et al., 1986; Lippitt et al., 2008; Conforti et al., 2014). Based on a recursive learning procedure, this algorithm uses a gradient descent of searching to minimize the model calibration errors (Kanellopoulos and Wilkinson, 1997).

Unlike the logistic regression, the BPN algorithm works without parametric assumptions (Lippitt et al., 2008) and allows the characterization of models containing non-linear relationships and dependence within and between predictor variables, without explicit definition of these relationships (Lek and Guegan, 1999). This advantage allows increasing the prediction accuracy of these models compared to parametric techniques such as LR (Manel et al., 1999; Lippitt et al., 2008). The independent variables are used to model the historical process of change, and the accuracy of the model should be above 75% to be considered acceptable (Eastman, 2012). The parameters used for the MLPNN were: 50% of the dataset for training sample and 50% for validation; 10000 iterations; the time factor equal to 0.5; sigmoid constant at 1.

5. Results

5.1 Land use and land cover changes

The results of land use and land cover spatial distribution classes highlights the forest cover class (Atlantic Forest) with the most significant rates of gain: 7.46%, 2.84% and 3.38% over the studied periods of change. The degraded pasture represented the land use class with largest reduction in area: -15.81%. In the years of 1985 and 2011, the managed pastures occupied the same proportion of land use (around 27% of the total area), and decreasing its proportion of occupied land in1995 and 2005. The areas occupied by managed pastures between 1985 and 2011 remained 53% stable in the Paraiba Valley. To understand the dynamics of LULCC it is necessary to assume that each class will swap over the years, meaning that whenever there is a decrease or increase of a class necessarily one or more classes should also suffer reductions or increases. The role of the change matrix (Table 2.2) is to bring to the knowledge the dynamic swapping processes, and at what rates they occur. Figure 2.3 shows the distribution and proportion of mapped classes in each year. The mapping overall accuracy for each year was 90.15% for 1985, 90.06% for 1995, 89.29% for 2005, and 88.48% for 2011.

Table 2.2. Land use and land cover change matrix of Paraíba Valley, São Paulo state, Brazil.

(km^2)	1985							
1995	d. pasture	agriculture	m. pasture	eucalyptus	Soil	built-up areas	Forest	Water
degraded pasture	3290.58	229.09	1995.52	63.71	200.68	93.95	331.7	25.27
agriculture	23.87	72.58	55.99	1.03	36.91	14.05	1.61	3.05
managed pasture	887.75	47.97	1572.03	12.25	120.38	39.33	25.21	11.18
eucalyptus	145.37	17.58	47.15	170.61	11.65	1.69	158.84	0.17
soil	71.32	43.49	108.51	4.79	83.33	18.08	6.32	7.27
built-up areas	48.11	44.94	102.75	1.33	33.51	215.74	3.24	9.48
forest	1219.41	82.83	140.26	119.28	34.59	10.28	2165.58	13.87
water	6.03	5.78	6.74	2.02	6.55	5.04	3.13	173.56
	1995							
2005	d. pasture	agriculture	m. pasture	eucalyptus	Soil	built-up areas	Forest	Water
degraded pasture	3691.71	37.76	754.98	73.27	78.86	66.55	486.01	7.75
agriculture	299.66	106.45	85.16	1.23	46.71	30.94	10.15	4.21
managed pasture	1137.86	18.31	1681.85	19.95	88.76	54.99	43.55	1.77
eucalyptus	113.11	2.39	56.63	213.25	7.31	1.71	95.29	0.32
soil	70.94	14.18	47.73	7.79	66.27	29.55	9.09	4.81
built-up areas	92.76	16.41	45.31	1.11	28.89	260.37	17.13	2.31
forest	797.56	8.72	37.41	235.99	10.95	5.71	3098.42	5.78
water	26.88	4.88	7.11	0.35	15.39	9.27	26.11	181.91
	2005							
2011	d. pasture	agriculture	m. pasture	eucalyptus	Soil	built-up areas	Forest	Water
degraded pasture	2467.98	62.24	499.57	23.72	32.49	18.79	289.16	6.59
agriculture	182.99	194.38	59.84	4.88	20.77	36.38	16.06	7.05
managed pasture	1425.86	251.65	2205.37	9.88	58.56	49.01	27.36	5.41
eucalyptus	192.73	6.98	113.19	321.86	13.55	1.81	213.26	0.45
soil	40.57	18.73	26.02	0.49	47.35	8.41	3.69	7.23
built-up areas	58.31	32.16	70.91	1.26	56.41	326.02	9.43	6.39
forest	812.37	12.27	68.18	127.21	8.14	19.52	3636.15	18.17
water	16.35	6.12	4.01	0.72	13.11	4.41	5.97	220.61

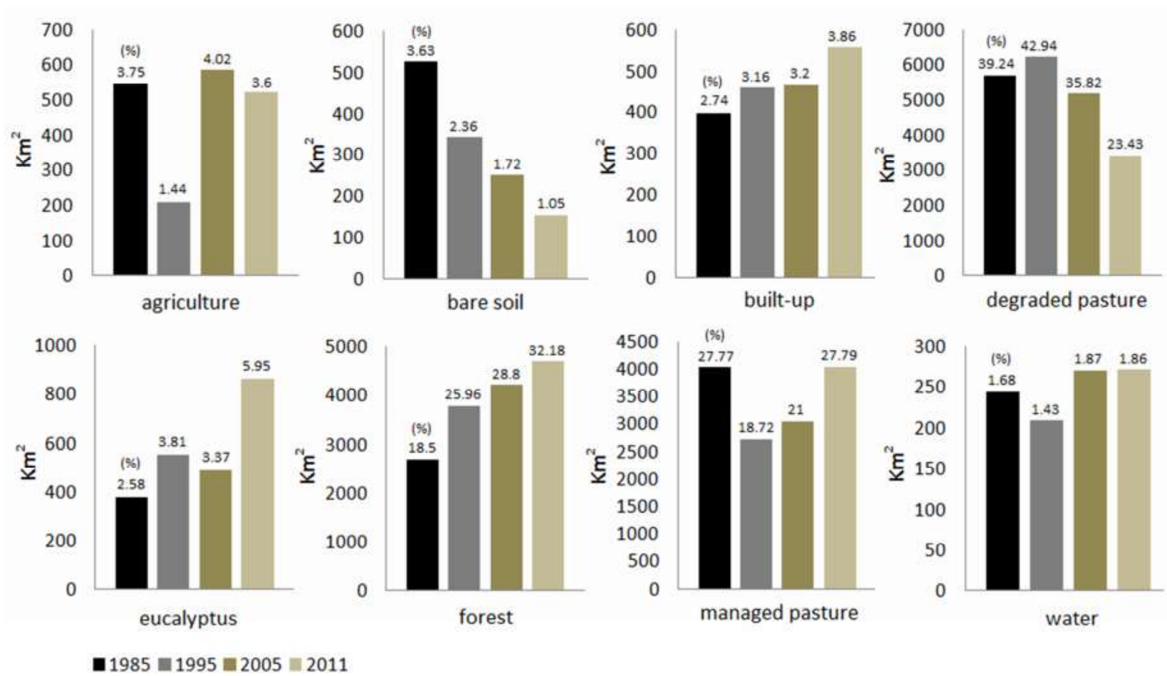

Figure 2.3. Land use and land cover in the Paraíba Valley. The graphics show each class extension in km^2, and the percentage (%) of each class in relation to the other classes.

The change matrix shows a dynamic landscape with a strong relationship between the classes of managed pasture, degraded pasture and forest. According to the data (Table 2.2), in the three periods of change, the class of degraded pasture made the largest contribution to new areas of forest, and at the same time it also had intense swapping with managed pastures. This trend indicates the abandonment of former pasturelands (increase of degraded pastures areas) as the factor most influential to the forest transition in the study region. The eucalyptus plantations had 48% of its growth over degraded pastures and 30% over managed pasture. Between the classes with more significant contribution to deforestation are pasturelands and eucalyptus. Among the years of 1985 and 2011 the urban areas increased 1.12%. According to the census data, in the early 1980s the rural population had decreased to 13.5%, and fell to 5.8% in 2010, while the urban population increased from 1118653 inhabitants in 1980 to 1804126 in 2010. Variations in population rates show that there has been significant population growth followed by an increase of built-up areas.

The agriculture class occupied a constant and small proportion of areas in 1985 and 2011, but decreased 2.31% during the first period of change, 1985/1995. These results suggest the stability of agricultural areas, especially those occupied by rice farming in the floodplains of the Paraiba River, where the relief is dominated by slopes smaller than 5%.

5.2 LULCC models and driving forces

The results of Cramer's V test reveal the explanatory power of the independent variables for each period of change (Table 2.3).

Table 2.3. Results of Cramer's V test for the set of independent variables.

	Cramer's V		
Independent variables	1985/1995	1995/2005	2005/2011
X_1	0.1586	0.1326	0.1167
X_2	0.2887	0.3038	0.2997
X_3	0.1537	0.1676	0.1536
X_4	0.1083	0.2755	0.1820
X_5	0.4624	0.6056	0.5469
X_6	0.1889	0.2050	0.2358
X_7	0.1339	0.1559	0.1729
X_8	0.2081	0.2274	0.2189
X_9	0.1435	0.1590	0.1643
X_{10}	0.1238	0.1211	0.1367
X_{11}	0.1319	0.1313	0.1624
X_{12}	0.1239	0.1645	0.1565
X_{13}	0.1432	0.1742	0.1309
X_{14}	0.1315	0.1257	0.1389
X_{15}	0.1271	0.1470	0.1347
X_{16}	0.1592	0.1606	0.1597
X_{17}	0.1198	0.1168	0.1342

The IDRISI software (version 17.01) used for data modeling presents an open version of the results generated by the method of multi-layer perception in the module "Land Change Modeler". Through the measures of accuracy and rate of learning, the MLPNN evaluates the sensitivity of the model taking into account the independent variables one by one. Thus, the MLPNN is able to register the importance (influence order) of each driving force in relation to the dependent variable (Table 2.4) and its ability to model the process of change.

Table 2.4.Results of the "Land Change Modeler" by the MLPNN method. The "IO" column in the table represents the influence order of each independent variable for the prediction of the model relative to the dependent variable (non-forest to forest). In ascending scale, the "IO" column shows the most influential driving force with the value 1. The last row ("all") means the general result for the model.

	1985/1995			1995/2005			2005/2011		
Variables	Accuracy	Skill Measure	IO	Accuracy	Skill Measure	IO	Accuracy	Skill Measure	IO
X_1	70.40	0.4079	2	-	-	-	-	-	-
X_2	75.74	0.5149	4	81.99	0.6399	5	77.73	0.5547	5
X_3	75.85	0.5171	6	81.47	0.6294	3	77.83	0.5567	6
X_4	-	-	-	80.21	0.6041	2	77.74	0.5494	2
X_5	66.28	0.3257	1	63.70	0.2739	1	62.07	0.2413	1
X_6	75.86	0.5173	7	82.38	0.6477	11	78.08	0.5615	9
X_7	-	-	-	82.28	0.6457	10	77.73	0.5547	4
X_8	75.84	0.5169	5	82.20	0.6441	8	78.11	0.5621	10
X_9	-	-	-	81.92	0.6385	4	78.04	0.5607	8
X_{11}	-	-	-	-	-	-	77.66	0.5533	3
X_{12}	-	-	-	82.03	0.6407	7	77.94	0.5587	7
X_{13}	-	-	-	82.01	0.6403	6	-	-	-
X_{16}	75.46	0.5093	3	82.23	0.6447	9	78.18	0.5636	11
all	76.18	0.5237	-	82.33	0.6467	-	78.10	0.5619	-

Table 2.4 shows the results of the models of change with the variables accepted by Cramer's V test for each period. The results presented in Table 2.3 showed variations in the number of variables with minimal explanatory power for each period indicating that the process under study is dynamic and without a linear or predictable relationship with all the same variables during the time series. As observed (Table 2.4), the variable X_5 (proximity to forest) played the major role to the increase of forest cover in all periods (1985/1995; 1995/2005; and 2005/2011). Among the socioeconomic variables, the variable X_3, which represents the number of rural houses per municipality, was the only one to have explanatory power above 0.15 in the three periods. The proximity to paved roads (X_6) had low influence for the increase of forest cover. The results (Table 2.4) indicate that the likelihood of forest cover regeneration increases with increasing distance from roads. Many studies have shown the influence of the proximity to roads on the deforestation and fragmentation processes, revealing the roads as driving forces of forest degradation (Freitas et al., 2010; Nepstad et al., 2001).

Regarding the LR method, similar results with those found by the MLPNN were observed, and for the last two periods of change there was greater similarity. By the

LR results, the variable X_5 was the most influential factor to the increase of forest cover, while X_6 had low importance. These results were measured by the ROC. The results of LR with all variables combined (multilogistic regression) in all periods of study had greater ROC values than the individual values for each single LR with one variable, indicating a good fit of the model with the selected variables. The ROC value for the multilogistic regression for the period 1985/1995 was 0.8403. For the successive periods it was 0.8598 and 0.8410, respectively.

6. Discussion

Theory, observation, and models are critical components in land use and land cover change research (Hersperger et al., 2010). With an extension of about 14500 km^2, the Paraíba Valley has shown intense change dynamics during the 27 years covered by this study. However, the dynamics of change between degraded pastures, managed pastures and forest were the most significant. Regarding the land use of monocultural forest plantations of eucalyptus, the results from the MLPNN model did not reach acceptable results and few independent variables had significant explanatory power. Thus, on the subject of eucalyptus, some observations were made from the LULCC data, and from the results of the models. According to Pontius Jr. et al. (2008), the accuracy of LULCC models is related to the amount of change observed in the reference maps. This study indicates that there is a tendency for better accuracy results in the models for the trajectories where larger amount of changes are observed, which may explain the unsatisfactory results for the attempts to model the changes in eucalyptus plantations.

The study region consists of 34 municipalities with numerous demographic and socioeconomic differences (Itani et al., 2011), and also exhibited during the three periods of change different rates of forest gain, forest stability and different dynamics in the eucalyptus plantation.

Figure 2.4 reveals patterns of forest cover dynamics, indicating different patterns of changes in the landscape, affected by the diversity of biophysical and socioeconomic factors present in each municipality. The maps also show a tendency of the forest cover stability in 2005/2011. These results highlight the complex and interdependent nature of the natural vegetation cover with the environment and to the human dimensions of these changes.

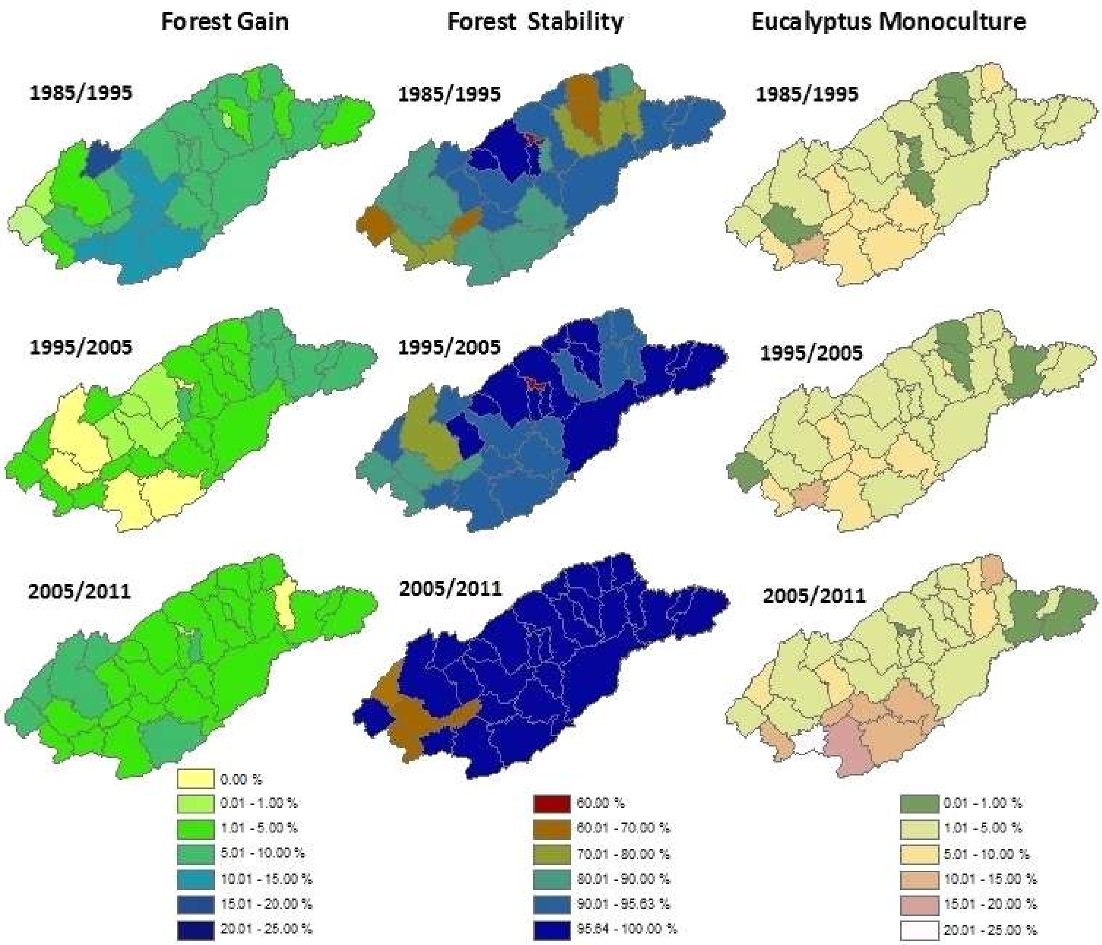

Figure 2.4. Proportion of forest gain, forest stability, and eucalyptus monoculture plantations in the Paraiba Valley, Brazil. "Forest gain" maps represent the percentage of increase in forest cover in the period of change minus the rate of loss by deforestation. "Forest Stability" is the area of forest that remained stable throughout the period of change. The maps for "eucalyptus monoculture" represent the portion of this land use in each municipality. The spatial unit of the maps is municipality.

6.1 Period of 1985/1995

The highest rate of forest gain was observed at this period, 7.46%, equivalent to 1082 km^2. According to the results from the model (Table 2.4), the variable X_5 had the greatest influence on the change predictions. This information indicates that the remaining forest cover is critical to the Atlantic Forest biome regeneration, as already observed by Lira et al. (2012). In this case, the recovery of the forest cover in the Atlantic Forest biome at Paraíba Valley is strongly associated with the proximity to forest remnants. The variable aspect (X_1) also showed a strong relationship in the prediction of change from non-forest to forest. It was observed that 34% of forest gain occurred on the North face while 56% over the South face, and 9% on flat areas. Other studies (Rosenberg et al., 1983; Bale et al., 1998; Mello, 2009) have shown the differences of solar radiation over the southern hemisphere, pointing the north faces of the southern hemisphere with greater insolation and consequently considered more productive for agricultural production. Thus, the increase of forest cover areas had a strong relationship with degraded pastures in the "opposite-faces", which are the sections of land surface located in the South face of the Paraíba Valley landscape, less suitable for agricultural practices than the North face. This phenomenon, which is related to the abandonment of land use can be partially explained by the farmer´s decision for the best lands to be dedicated for agricultural use, and in part by the role of the São Paulo State Decree, n^0 28848 of 1988, that banned the practice of burning to prevent the use of fire for the control and management of pasturelands. According to the technical report about the region, this policy had impact on the maintenance of grasslands on the "opposite-faces", where the cost-benefit for the management of pastures without the use of fire and just by manual weeding, became disadvantageous, leading to the abandonment of many of these areas.

Third variable in order of influence in the MLPNN model, the variable X_{16} reveals relevant influence on the skill measure and model accuracy. In slopes of 20% to 75%, the forest cover increased 72%. The Paraíba Valley landscape, characterized as a "sea of hills", has an strong influence on the decision making process for land use and favors conservation (Mello, 2009).

6.2 Period of 1995/2005

Presented in the results section, the variable X_5 (proximity to forest remnants) was the driving force with greater influence on the forest regeneration process in all periods studied. This result was the same for the LR and to the MLPNN; and its relationship with the forest cover dynamic already discussed in the previous section (*Period of 1985/1995*). Unlike the first period of change, the variable X_1 did not have enough explanatory power, therefore it was not included in the model. In this period, new socioeconomic variables presented explanatory power above 0.15 and were incorporated into the model. Based on the general result of MLPNN, the variable X_5 (proximity of forest) had significantly higher influence in the model than the other independent variables that presented less influence on the variation of skill measure and in the model accuracy.

The proximity to eucalyptus plantation (X_4) was the second variable in the influence order on the model, suggesting a tendency of forest cover increase nearby this land use. With approximately 80851ha of own lands, the largest forestry company operating in the Paraíba Valley, had approximately 44% of its total area covered by eucalyptus plantations between the years of 1995 and 2005. According to the data in Table 2.5, the forest cover class in these areas increased from 12.3% in 1985 to 31.25% in 2005. The trend observed in the private lands of this company - the increase of eucalyptus plantation and forest cover, and the abandonment of agricultural land use - is observed in other lands where there was the introduction of eucalyptus cultivation in the Paraíba Valley (Eskinazi and Souza, 2013; Farinaci et al., 2013). Thus, the results indicate that eucalyptus has exerted a positive influence on the increase of forest cover in the Atlantic Forest in the Paraíba Valley, at the same time that it brought impacts on rural livelihoods and on landscape heterogeneity (Eskinazi and Souza, 2013; Farinaci et al., 2013).

Table 2.5. Variation rates of LULC classes within private lands of the forestry company operating in Paraíba Valley. The private land areas totalize 80851 hectares.

	LULC classes (%)					
	Eucalyptus	Forest	Agriculture	Managed pasture	Degraded pasture	Soil
1985	17.17	12.03	3.31	25.43	38.01	3.19
1995	21.76	24.04	0.27	16.08	36.68	1.21
2005	26.07	31.25	0.79	12.15	26.07	1.28
2011	46.01	34.35	1.08	5.81	11.79	0.11

Farinaci et al. (2013) call attention to the globalized market of eucalyptus production in the Paraíba Valley, which is focused on international trade, and follows strict international protocols such as the Forest Stewarship Council (FSC) certification program and the Brazilian Program of Forest Certification (Cerflor), both of which had positive impacts on the conservation of Atlantic Forest remnants.

In this period, two socioeconomic variables were highlighted in the influence order of drivers to the model: X_3 (rural houses) and X_9 (farm credit). It was observed for the variable X_3 that 34% of forest gain occurred in seven municipalities with the number of permanent rural dwelling below the average of the thirty four municipalities. For the variable X_9 it was observed that 54% of forest gain occurred in ten municipalities with farm credit below the average for municipalities in the Paraíba Valley. For example, the municipality of Cunha, with the highest rate of change from non-forest to forest, had one of the lowest farm credit allocations suggesting the following trend: the smaller the farm credit in a particular municipality, the greater the likelihood of forest cover increase in the same period.

6.3 Period of 2005/2011

Between the years of 2005 and 2011 the variables X_4 (proximity to eucalyptus) and X_5 (proximity to forest remnants) kept their importance on the dynamic process of forest regeneration. However, at this time, there were changes in the order of socioeconomic variables with greatest importance on the influence order of the model. According to the result of MLPNN, the third variable with high influence on the changes was the number of industries and commerce (X_{11}). The analysis of this variable indicates that 9 of the 34 municipalities of Paraíba Valley concentrated 85% of all industries and commercial establishments in 2005. Regarding the total forest gain between 2005 and 2011, 33.5% occurred in these 9 municipalities. The proportion of forest increasing in these municipalities was 3.8%, and 1.9% in the other 25 municipalities. These results provide relevant support for Forest Transition theory (Rudel et al., 2005; Rudel et al., 2010), as the economic development, which in this case is represented by industrialization and commerce, is a vector for the return process of forest vegetation in their areas of influence.

39% of the forest cover growth occurred in 19 municipalities with below average availability of farm jobs. Thus, the rate of forest gain was equivalent to 2% for each municipality with less than 272 formal jobs in agriculture (X_7), while for those above average, it was 4%. This result indicates a trend of higher increase of forest in the municipalities with the largest number of farm jobs. From these results and socioeconomic information about the region, it is clear that the sectors of agribusiness and rural tourism (rural tourism, ecotourism and historical tourism) may have played a significant role in explaining this relationship, because they are business sectors that require employment, and generate income thereby providing opportunity costs for local population (Couto and Serra, 2011; Izique, 2012; Roque, 2013). Rural tourism is relevant to generating income and employment in rural areas through non-agricultural activities, and to stimulate the restoration and conservation of natural environments (Roque, 2013).

In São Paulo state, in 2009, 79% of rural income came from non-agricultural activities (Izique, 2012). The development of formal job activities in rural areas unlinked to the livestock and agriculture practices, and more focused on agribusiness, forestry, tourism and leisure sectors, may reflect on the intensification or abandonment of agricultural land use, and for conservation practices such as environmental restoration and establishment of agroforestry systems, both with favorable consequences on forest cover.

6.4 Summary of Forest Transition process in the Paraíba Valley

To clarify the broad context behind forest transitions in the Paraíba Valley, São Paulo State, Brazil, Figure 2.5 was developed to synthesize the most important processes. Forest recovery was related to many drivers with different intensities in each period of change. This dynamic process reveals a very complex context and should be understood at local scales (e.g., municipalities) as a bottom-up perspective, suitable to highlight complex LULCC contexts. For this study case, through the Paraíba Valley geographic, historic and development perspectives, the local context is relevant to capture dimensions of the land use, such as topography, economic policies (farm credit), and economic development, linked with the changes observed in time.

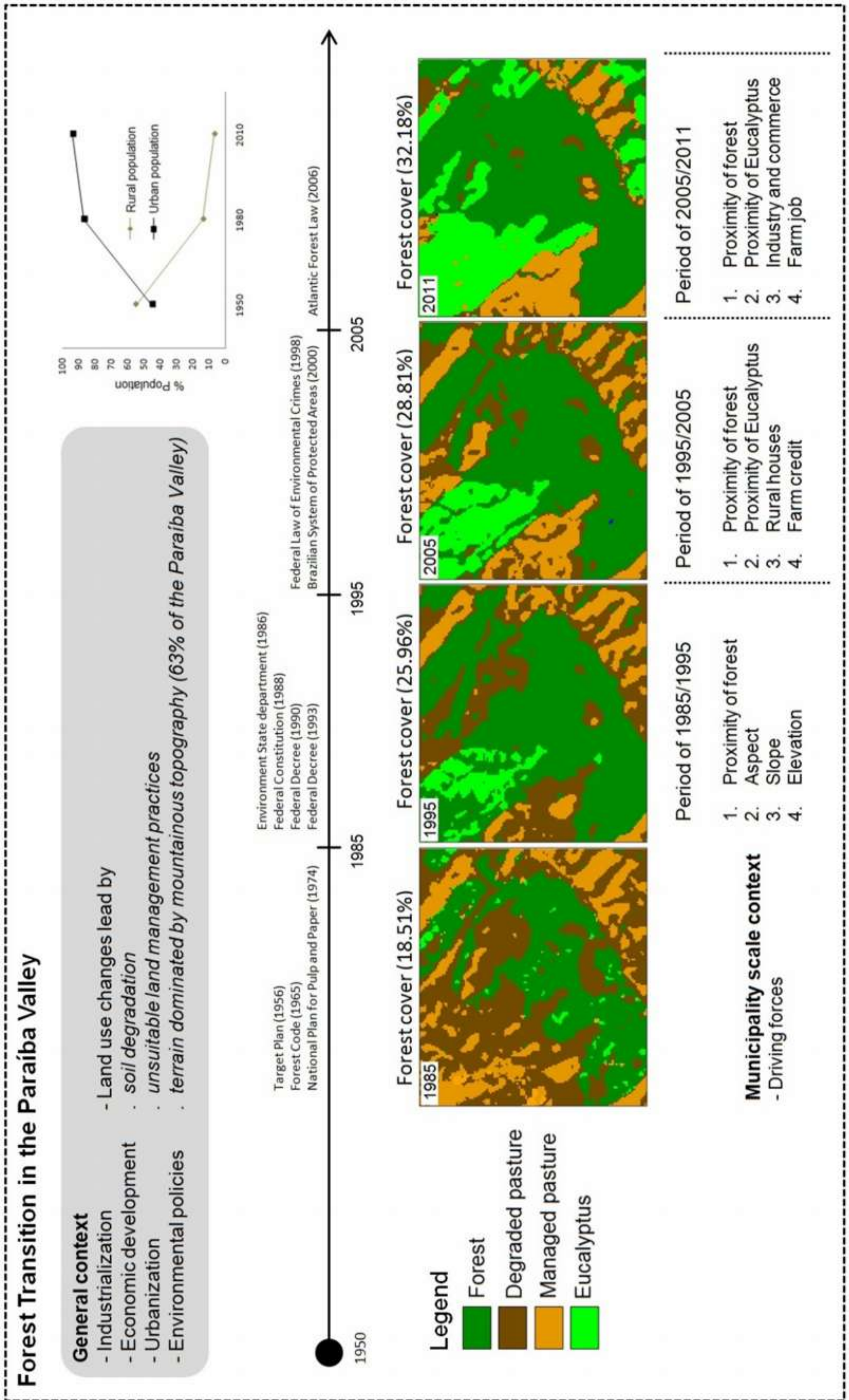

Figure 2.5.Summary of Forest Transition process in the Paraíba Valley.

7. Conclusions

The results observed in Table 2.2 show that land use and land cover changes in the Paraíba Valley had consequences on the increase of forest cover. Models are tools to support the analysis of causes and consequences of changes in land use (Verburg et al., 2004), and the LULCC models were key to understand the phenomenon studied. As a result, among the 17 independent variables selected for the study, 14 presented explanatory power above 0.15 (Cramer's V). For the three periods studied, different degrees of influence from these variables on the dependent variable (non-forest to forest) dynamic were observed. Thus, it was concluded that there is not a major driving force on the process of change modeled, but a group of them, interacting at different levels and for each period—not surprising in a complex and dynamic system such as this one.

The biophysical variables of the landscape related to the topography had a strong influence on the dynamics of forest cover between 1985 and 1995, but lost influence in later periods. Similarly, socioeconomic variables that showed no significant influence on forest cover in the same period (1985 and 1995), became more influential between 1995 and 2011. Such information shows that in the Paraíba Valley, areas most susceptible to Atlantic Forest regeneration are those with topography less favorable for agricultural and livestock use. As these areas are replaced by forest cover, these biophysical variables become less significant giving way to other factors more related to social and economical characteristics, which act at local scales of the landscape (e.g., municipality).

From the perspective of LULCC modeling, the statistical multilogistic regression model resulted in ROC values above 0.8, indicating a good fit of these models to the process analyzed, similarly for the MLPNN results with accuracy above 75%. Through the presentation format of the "Land Change Modeler" results for the MLPNN it was possible to obtain individual information about the influence of each variable on the land change process modeled. This crucial information to the research goals have made it possible to identify and discuss the driving forces with more influence to the forest transition in the years of 1985 and 1995, 1995 and 2005, and 2005 and 2011. The theoretical and empirical knowledge about the reality analyzed constitute essential inputs for critical reading, understanding and discussion of the results from the land use and land cover change models.

References

Ab'Saber, Aziz Nacib. 2003. Os domínios de natureza no Brasil: potencialidades paisagísticas [The Natural Areas of Brazil: landscape potentialities]. São Paulo: Ateliê Editorial, 6ªed.

Alves, E., Souza, G. S., Marra, R., 2011. Êxodo e sua contribuição à urbanização de 1950 a 2010. Política Agrícola 2:80-88.

Arsanjani, J. J., 2012. Dynamic Land-Use/Cover Change Simulation: Geosimulation and Multi Agent-Based Modeling. Berlin: Springer.

Bale, C. L., Williams, J. B., Charley, C. L., 1998. The impact of aspect on forest structure and floristics in some Eastern Australian sites. Forest Ecology and Management 110(1-3): 363–377. doi. 10.1016/S0378-1127(98)00300-4.

Baumann, M., Ozdogan, M., Kuemmerle, T., Wendland, K. J., Esipova, E., Radeloff, V. C., 2012. Using the Landsat record to detect forest-cover changes during and after the collapse of the Soviet Union in the temperate zone of European Russia. Remote Sensing of Environment 124: 174-184. doi. 10.1016/j.rse.2012.05.001.

Baptista, S. R., 2008. Metropolitanization and Forest Recovery in Southern Brazil: a Multiscale Analysis of the Florianópolis City-Region, Santa Catarina State, 1970 to 2005. Ecology and Society 13(2).

Beilin, R., Lindborg, R., Stenseke, M., Pereira, H. M., Llausas, A., Slätmo, E., Cerqueira, Y., Navarro, L., Rodrigues, P., Reichelt, N., Munro, N., Queiroz, C., 2014. Analysing how drivers of agricultural land abandonment affect biodiversity and cultural landscapes using case studies from Scandinavia, Iberia and Oceania. Land Use Policy 36: 60–72. doi. 10.1016/j.landusepol.2013.07.003.

Bieling, C., Plieningerb, T., Schaich, H., 2013. Patterns and causes of land change: Empirical results and conceptual considerations derived from a case study in the

Swabian Alb, Germany. Land Use Policy 35:192–203. doi. 10.1016/j.landusepol.2013.05.012.

Boffi, S. A. N. O., Ricci, F., Oliveira, E. A. A. Q., 2006. Análise histórica da região do Vale do Paraíba como atrativo para a implantação da indústria de base (1930 - 1980). *Revista Univap* 13(24): 3059–3063.

Borgonovi, M., Chiarini, J. V., Amaral, A. Z., Coelho, G. S., Oliveira, D. A., 1967. Cobertura Vegetal do Estado de São Paulo [Vegetal Cover of São Paulo State]. Bragantia 26(6): 95–102.

Brandão, Luiz Fernando, ed., 2012. Relatório de sustentabilidade 2011 [Report of Sustainability 2011]. São Paulo: FIBRIA.

Brito, F., 2006. O deslocamento da população brasileira para as metrópoles. Estados Avançados 20: 221–236.

Brondizio, E., 2009. Análise Intra-regional de mudanças do uso da terra na Amazônia. *In* Ecossistemas Florestais: interação homem-ambiente. Moran, E. F., Ostrom, E., eds., Pp. 289–326. São Paulo: Senac/Edusp.

Bürgi, M., Hersperger, A. M., Schneeberger, N., 2004. Driving forces of landscape change—current and new directions. Landscape Ecology 19: 857–868. doi. 10.1007/s10980-004-0245-8.

Calixto, J. S., Ribeiro, A. E. M., 2007. Três olhares sobre o reflorestamento: a percepção de atores sociais sobre a monocultura de eucalipto no Alto Jequitinhonha, MG. Organizações Rurais e Agroindustriais 9: 437–450.

Conforti, M., Pascale, S., Robustelli, G., Sdao, F., 2014. Evaluation of prediction capability of the artificial neural networks for mapping landslide susceptibility in the Turbolo River catchment (northern Calabria, Italy). Catena 113: 236–250. doi. 10.1016/j.catena.2013.08.006.

Chavez, P. S., 1988. An improved dark-object subtraction technique for atmospheric scattering correction of multispectral data. Remote Sensing of Environment 24: 459–479. doi. 10.1016/0034-4257(88)90019-3.

Couto, M. F. R., Serra, E., 2011. Vale do Paraíba: da economia cafeeira à sustentável. Revista Geográfica de América Central 2(47E): 1–15.

Dean, W., 1996. A Ferro e Fogo: História de uso e ocupação da Mata Atlântica. São Paulo: Cia. das Letras.

Drummond, José Augusto., 1997. Devastação e preservação ambiental: os parques nacionais do Estado do Rio de Janeiro. Niteroi: EDUFF.

Eastman, J. R., 2012. IDRISI Selva Tutorial: Manual Version 17.01. Worcester: Clark Labs.

Ellis, E. A., Baerenklau, K. A., Marcos-Martínez, R., Chávez, E., 2010. Land use/land cover change dynamics and drivers in a low-grade marginal coffee growing region of Veracruz, Mexico. Agroforest Systems 80: 61–84. doi. 10.1007/s10457-010-9339-2.

EMBRAPA (Empresa Brasileira de Pesquisa Agropecuária), 2006. National Service for Survey and Conservation of the Soil: Brazilian System of Soil Classification. Rio de Janeiro: EMBRAPA.

Eskinazi, B. G., Souza, J. G., 2013. Expertise production and territorial Homogenization: eucalyptus monoculture in the Valley of Paraíba and production dynamic changes. Mundo do Trabalho 14(2): 194–2011.

Evans, T. P., Munroe, D. K., Parker, D. C., 2005. Modeling land-use/land cover change: Exploring the dynamics of human-environment relationships. *In* Seeing the Forest and Trees: Human-Environment Interactions in Forest Ecosystems. Moran, E. F., Ostrom, E., eds. Pp. 187–213. Cambridge, MA: MIT Press.

FAO (Food and Agriculture Organization of the United Nations), 2011. State of the world's forests. Rome: FAO.

Farinaci, J. S., Batistella, M., 2012. Variation on native vegetation cover in São Paulo: an overview of current knowledge. Revista Árvore 36(4): 695–705. doi. 10.1590/S0100-67622012000400011.

Farinaci, J. S., 2012. The new Forests in São Paulo State: a multiscalcar study under the perspective of the Forest Transition Theory. PhD diss., University of Campinas.

Farinaci, J. S., Ferreira, L. C., Batistella, M., 2013. Forest transition and ecological modernization: eucalyptus forestry beyond good and bad. Ambiente e Sociedade XVI: 25–44. doi. 10.1590/S1414-753X2013000200003.

Ferreira, G. M. V., Oliveira, L., Talamini, E., 2006. Posicionamento Estratégico das Cooperativas Agropecuárias de Leite: O Caso da Cooperativa de Lorena e Piquete no Vale do Paraíba. Paper presented at the XLIV Congress of SOBER: Administração Rural e Gestão do Negócio, Fortaleza, July 23.

Foster, D. R., Motzkin, G., Slater, B., 1998. Land-use history as long-term broad-scale disturbance: regional forest dynamics in Central New England. Ecosystems 1: 96–119. doi. 10.1007/s100219900008.

Freitas Junior, G., Marson, A. A., Solera, D. A. G., 2012. The Eucalyptus in the Paraíba Valley: historic and geographic aspects. Revista Geonorte 1(4): 221–237.

Freitas, J. C., 2008. A Política Agrícola do Regime Militar de 1964: aspectos jurídicos, financeiros e socioeconômicos. 107 p. Dissertation (Master degree in Constitutional Law) – University of Fortaleza, Fortaleza.

Freitas, S. R., Hawbaker, T. J., Metzger, J. P., 2010. Effects of roads, topography, and land use on forest dynamics in the Brazilian Atlantic Forest. Forest Ecology and Management 259(3): 410–417. doi. 10.1016/j.foreco.2009.10.036.

Fundação SOS Mata Atlântica/INPE, 2012. Atlas dos remanescentes de Mata Atlântica período 2011-2012. São Paulo: Fundação SOS Mata Atlântica/INPE.

Geist, H. J., Lambin, E. F., 2002. Proximate causes and underlying driving forces of tropical deforestation. Bioscience 52: 143–150. doi. 10.1641/0006-3568(2002)052[0143:PCAUDF]2.0.CO;2.

Geoghegan, J., Villar, S. C., Klepeis, P., Mendoza, P. M., Himmelberger, Y. O., Chowdhury, R. R., 2001. Modeling tropical deforestation in the southern Yucatan peninsular region: comparing survey & satellite data. Agriculture, Ecosystems and Environment 85: 25–46. doi. 10.1016/S0167-8809(01)00201-8.

Griffiths, P., Kuemmerle, T., Kennedy, R. E., Abrudan, I. V., Knorn, J., Hostert, P., 2012. Using annual time-series of Landsat images to assess the effects of forest restitution in post-socialist Romania. Remote Sensing of Environment 118: 199–214. doi. 10.1016/j.rse.2011.11.006.

Hecht, S. B., Kandel, S., Gomes, I., Cuellar, N., Rosa, H., 2006. Globalization, forest resurgence, and environmental politics in El Salvador. World Development 34: 308–323. doi. 10.1016/j.worlddev.2005.09.005.

Hersperger, A. M., Gennaio, M. P., Verburg, P. H., Bürgi, M., 2010. Linking land change with driving forces and actors: four conceptual models. Ecology and Society 15(4).

Hietel, E., Waldhardt, R., Otte, A., 2007. Statistical modeling of land-cover changes based on key socio-economic indicators. Ecological Economics 62: 496–507. doi. 10.1016/j.ecolecon.2006.07.011.

Hu, Z., Lo, C. P., 2007. Modeling urban growth in Atlanta using logistic regression. Computers, Environment and Urban Systems 31: 667–688. doi. 10.1016/j.compenvurbsys.2006.11.001.

IBGE (Instituto Brasileiro de Geografia e Estatística). Censos demográficos de 1950, 1960, 1970, 1980, 1991, 2000 e 2010. Disponível em: <http://www.sidra.ibge.gov. br>. Accessed in March, 2014.

Itani, M. R., Barros, C. M., Figueiredo, F. E. L., Andrade, M. R. M., Mansor, M. T. C., Mangabeira, R. L., Carvalho, V. S., eds., 2011. Subsídios ao planejamento ambiental: Unidade de Gerenciamento de Recursos hídricos Paraíba do Sul. São Paulo: SAM.

Izique, C. O, 2012. Brasil rural não é só agrícola. Pesquisa Fapesp (Special edition) 202-207.

Kanianska, R., Kizeková, M., Novácek, J., Zeman, M., 2014. Land-use and land-cover changes in rural areas during different political systems: A case study of Slovakia from 1782 to 2006. Land Use Policy 36: 554–566. doi. 10.1016/j.landusepol.2013.09.018.

Kanellopoulos, I., Wilkinson, G. G., 1997. Strategies and best practice for neural network image classification. Int. J. Remote Sensing 18(4): 711–725. doi. 10.1080/014311697218719.

Lambin, E. F., Meyfroidt, P., 2010. Land use transitions: Socio-ecological feedback versus socio-economic change. Land Use Policy 27: 108–118. doi. 10.1016/j.landusepol.2009.09.003.

Lambin, E. F., Geist, H. J., Lepers, E., 2003. Dynamics of Land-Use and Land-Cover Change in Tropical Regions. Annu. Rev. Environ. Resour. 28: 205–241. doi. 10.1146/annurev.energy.28.050302.105459.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., Coomes, O. T., Dirzo, R., Fischer, G. U., Folke, C., George, P. S., Homewood, K., Imbernon, J., Leemans, R., Li, X., Moran, E. F., Mortimore, M., Ramakrishnan, P. S., Richards, J. F., Skaanes, H., Steffen, W., Stone, G. D., Svedin, U., Veldkamp, T. A., Vogel, C., Xu, J., 2001. The Causes of Land-Use and Land-Cover Change: Moving Beyond the Myths. Global Environmental Change 11: 261–269. doi. 10.1016/S0959-3780(01)00007-3.

Lek, S., Guegan, J. F., 1999. Artificial neural networks as a tool in ecological modeling, an introduction. Ecological Modelling 120: 65–73. doi. 10.1016/S0304-3800(99)00092-7.

Lima, A. R., Capobianco J. P. R., 1997. Mata Atlântica: avanços legais e institucionais para sua conservação. São Paulo: ISA.

Lippitt, C. D., Rogan, J., Toledano, J., Sangermano, F., Eastman, J. R., Mastro, V., Sawyer, A., 2008. Incorporating anthropogenic variables into a species distribution model to map gypsy moth risk. Ecological Modelling 210: 339–350. doi. 10.1016/j.ecolmodel.2007.08.005.

Lira, P. K., Tambosi, L. R., Ewers, R. M., Metzger, J. P, 2012. Land-use and Land-cover change in Atlantic Forest Landscapes. Forest Ecology and Management 278: 80–89. doi. 10.1016/j.foreco.2012.05.008.

Lu, D., Weng, Q., 2007. A survey of image classification methods and techniques for improving classification performance. International Journal of Remote Sensing 28(5): 823–870. doi. 10.1080/01431160600746456.

Machado, A. M. B., Drummond, G. M., Paglia, A. P., 2008. Livro vermelho da fauna brasileira ameaçada de extinção. 1 ed. Brasília: MMA e Fundação Biodiversitas.

Manel, S., Dias, J., Ormerod, S. J., 1999. Comparing discriminant analysis, neural networks and logistic regression for predicting species distributions: a case study with a Himalayan river bird. Ecological Modelling 120: 337–347. doi. 10.1016/S0304-3800(99)00113-1.

Mather, A. S., Fairbairn, J., Needle, C. L., 1999. The course and drivers of the forest transition: the case of France. Journal of Rural Studies 15: 65–90. doi. 10.1016/S0743-0167(98)00023-0.

Matricardi, E. A. T., Skole, D. L., Pedlowski, M. A., Chomentowski, W., Fernandes, L. C., 2010. Assessment of tropical forest degradation by selective logging and fire using Landsat imagery. Remote Sensing of Environment 114: 1117–1129. doi. 10.1016/j.rse.2010.01.001.

Mcconnell, W. J., Sweeney, S. P., Mulley, B., 2004. Physical and social access to land: spatio-temporal patterns of agricultural expansion in Madagascar. Agriculture, Ecosystems and Environment 101: 171–184. doi. 10.1016/j.agee.2003.09.012.

Mello, T. F., 2009. Estrutura da vegetação, cobertura florestal e preferências de uso da paisagem associadas a vertentes: as quase-florestas de São Luiz do Paraitinga (SP). 86 p. Dissertation (Institute of Biosciences – Ecology) – University of São Paulo, São Paulo.

MMA (Ministério do Meio Ambiente), 2008. Instrução Normativa n^{0} 06, de 23 de setembro de 2008.

MT (Ministério dos Transportes), 2006. Plano Nacional de Logística e Transportes – PNLT. Brasília: MT.

Moran, E. F., Ostrom, E., eds., 2005. Seeing the Forest and Trees: Human-Environment Interactions in Forest Ecosystems. Cambridge: MIT Press.

Nepstad, D., Carvalho, G., Barros, A. C., Alencar, A., Capobianco, J. P. R., Bishop, J., Moutinho, P., Lefebvre, P., Silva JR., U. L., Prins, E., 2001. Road paving, the regime feedbacks, and the future of Amazon forests. Forest Ecology and Management 154: 395–407. doi. 10.1016/S0378-1127(01)00511-4.

Olden, J. D., Jackson, D. A., 2001. Fish-habitat relationships in lakes: gaining predictive and explanatory insight using artificial neural networks. Trans. Am. Fisheries Soc. 130: 878–897. doi. 10.1577/1548-8659(2001)130<0878:FHRILG>2.0.CO;2.

Oliveira, J. B., Camargo, M. N., Rossi, M., Calderano Filho, B., 1999. Mapa pedológico do Estado de São Paulo: legenda expandida. Campinas: Instituto Agronômico/EMBRAPA-Solos.

Perz, S. G., 2007. Grand Theory and Context-Specificity in the Study of Forest Dynamics: Forest Transition Theory and Other Directions. The Professional Geographer 59(1): 105–114. doi. 10.1111/j.1467-9272.2007.00594.x.

Pontius JR, R. G., Boersma, W., Castella, J. C., Clarke. K., Nijs, T., Dietzel, C., Duan, Z., Fotsing, E., Goldstein, N., Kok, K., Koomen, E., Lippitt, C. D., Mcconnell, W., Sood, A. M., Pijanowski, B., Pithadia, S., Sweeney, S., Trung, T. N., Veldkamp, A. T., Verburg, P. H., 2008. Comparing the input, output, and validation maps for several models of land change. Ann RegSci 42: 11–37. doi. 10.1007/s00168-007-0138-2.

Prishchepov, A. V., Müller, D., Dubininc, M., Baumann, M., Radeloff, V. C., 2013. Determinants of agricultural land abandonment in post-Soviet European Russia. Land Use Policy 30: 873–884. doi. 10.1016/j.landusepol.2012.06.011.

Queiroz, L. R. S., Barrichelo, L. E. G., 2008. A celulose de Eucalipto: uma oportunidade brasileira. Vinhedo: Avisbrasilis.

Ribeiro, M. C., Metzger, J. P., Martensen, A. C., Ponzoni, F. J., Hirota, M. M., 2009. The Brazilian Atlantic Forest: How much is left, and how is the remaining forest distributed? Implications for conservation. Biological Conservation 142: 1141–1153. doi. 10.1016/j.biocon.2009.02.021.

Ricci, F., 2008. A economia cafeeira no Vale do Paraíba paulista na República Velha: uma avaliação. Revista Brasileira de Gestão e Desenvolvimento Regional 4: 105–117.

Rodrigues, R. R., Gandolfi, S., 2007. Regrowth actions. *In* High diversity forest regrowth in degraded areas. Rodrigues, R. R., Martins, S. V., Gandolfi, S., eds., Pp. 77–102. New York: Nova Science.

Roque, A., 2013. Estudo Preliminar da Cadeia Produtiva: Turismo Rural Brasil. Brasília: IICA Brasil.

Rosenberg, N. J., Black, B. L., Verma, S. B., 1983. Microclimate: the biological environment, 2nd Edition. Chichester: John Wiley & Sons.

Rudel, T. K., Schneider, L., Uriarte, M., 2010. Forest transitions: An introduction. Land Use Policy 27: 95–97. doi. 10.1016/j.landusepol.2009.09.021.

Rudel, T. K., Coomesb, O. T., Moran, E., Achardd, F., Angelsene, A., Xuf, J., Lambin, E., 2005. Forest transitions: towards a global understanding of land use change. Global Environmental Change 15: 23–31. doi. 10.1016/j.gloenvcha.2004.11.001.

Rumelhart, D., Hinton, G., Williams, R., 1986. Learning internal representations by error propagation. *In* Parallel Distributed Processing: Explorations in the Microstructures of Cognition. Rumelhart, D. E., Mcclelland, J. L., eds., Pp. 318–362. Cambridge: MIT Press.

Sánchez-Cuervo, A. M., Aide, T. M., Clark, M. L., Etter, A., 2012. Land Cover Change in Colombia: Surprising Forest Recovery Trends between 2001 and 2010. PLOS ONE 7(8): 1–14. doi. 10.1371/journal.pone.0043943.

SAA/CATI/IEA. (Secretaria de Agricultura e Abastecimento/Coordenadoria de Assistência Técnica Integral/Instituto de Economia Agrícola). Projeto LUPA 1995/96: Censo Agropecuário do Estado de São Paulo. Available in: <http://www.cati.sp.gov.br/projetolupa/dadosmunicipais9596.php>. Accessed in March, 2014.

SAA/CATI/IEA. (Secretaria de Agricultura e Abastecimento/Coordenadoria de Assistência Técnica Integral/Instituto de Economia Agrícola). Projeto LUPA 2007/08: Censo Agropecuário do Estado de São Paulo. Available in: < http://www.cati.sp.gov.br/projetolupa/dadosmunicipais.php>. Accessed in March, 2014.

Serneels, S., Lambin, E. F., 2001. Proximate causes of land-use change in Narok District, Kenya: a spatial statistical model. Agriculture, Ecosystems and Environment 85: 65–81. Doi. 10.1016/S0167-8809(01)00188-8.

Siles, N. J. S., 2009. Spatial Modeling and Prediction of Tropical Forest Conversion in the Isiboro Sécure National Park and Indigenous Territory (TIPNIS), Bolivia. 83p. Thesis (Master in Geo-information Science and Earth Observation) – International Institute of Geo-information Science and Earth Observation, Enschede.

Silva, R. F. B., Araos-Leiva, F., Farinaci, J. S., Ferreira, L. C., 2012. Monocultivos de Eucalipto, Reflexividade e Arena: Diálogos Interdisciplinares em Ambiente e Sociedade. Terceiro Incluído 2: 32–50.

Silvestre, D., Rodriguez, M. E., 2007. Eucalipto/Aracruz Celulose e violações de direitos humanos. Rio de Janeiro: PAD.

Teixeira, A. M. G., Soares-FILHO, B. S., Freitas, S. R.; Metzger, J. P., 2009. Modeling landscape dynamics in na Atlantic Rainforest region: Implications for conservation. Forest Ecology and Management 257: 1219–1230. doi. 10.1016/j.foreco.2008.10.011.

Tucker, C. M., Southworth, J., 2005. Processos de mudança florestal em nível local e de paisagem em Honduras e Guatemala. *In* Seeing the Forest and Trees: Human-Environment Interactions in Forest Ecosystems. Moran, E. F., Ostrom, E., eds. Pp. 327–354. Cambridge, MA: MIT Press.

Vieira, E. T., 2009. Industrialização e política de desenvolvimento regional: o Vale do Paraíba na segunda metade do século XX. 177 p. Tese (PhD.In Economic History) – University of São Paulo, São Paulo.

Vieira, E. T., Santos, M. J., 2012. Industrialização e desenvolvimento regional: política do CODIVAP no Vale do Paraíba na década de 1970. Desenvolvimento Regional em debate, 2: 161–181.

Verburg, P. H., Schot, P., Dijst, M., Veldkamp, A., 2004. Land use change modelling: current practice and research priorities. GeoJournal 61: 309–324. doi. 10.1007/s10708-004-4946-y.

Zuquim, M. L., 2007. Os caminhos do rural: uma questão agrária e ambiental. São Paulo: SENAC.

Ye, B., Huang, F., Zhang, F., Zhang, Y., 2001. The Driving Forces of Land Use/Cover Change in the Upstream Area of the Nenjiang River. Chinese Geographical Science, 11(4): 377–381. doi. 10.1007/s11769-001-0054-9.

Yu, N., Qingyun, D., 2011. Urban Growth Pattern Modeling Using Logistic Regression. Geo-spatial Information Science 14(1): 62–67. doi. 10.1007/s11806-011-0427-x.

Capítulo III

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Contexts of Forest Transition in the Paraíba Valley: Public Policies, Socioeconomic Changes and Land Use

Abstract: The industrialization of the Paraíba Valley since the 1950s, has been driven by an intense urbanization process while, at the same time other municipalaties far from the economic center economically stagnated until the start of the 21th century. Despite the economic differences and an unequal distribution of the population in the Paraíba Valley, all the municipalities share the same relief characteristics with a terrain dominated by slopes of over 20% (63% of Paraíba Valley). Historically the land has been occupied by coffee plantations since the beginning of the 20th century, dairy production followed, but it too declined in the 1980s. The depletion of the soil's productive capacity after land use cycles without management practices suitable for these landscape conditions was a common cause of this decline, which has resulted in land use abandonment. This research analyzed public information, land use/cover maps, environmental public policies, and also interviewed stakeholders from Federal and State agencies, municipal departments of environment and agriculture, civil society and farmers, with the aim of understanding the contexts behind the forest transition in the Paraíba Valley, São Paulo State, Brazil. Although the existence of two Forest Transition (FT) pathways have been noted (economic development pathway and the forest scarcity pathway), there are many contexts that shape the model of FT observed in each particular region. This means that local conditions, such as relief, soil quality, historic land use/cover, public policies, the engagement of society in compliance with legal regulations, and the action of enforcement agencies, represent dimensions which, combined, create contexts that enable forest regeneration. This perspective allows us to understand the Forest Transition process in the Paraíba Valley since the 1960s.

Key words: public policies, law enforcement, socioeconomic changes, social engagement, forest regeneration.

1. Introduction

Several theories have been developed over the past two centuries looking to make sense of the relations between human demands (for land, food and natural resources) and the environment. In the early 19th century, Thomas Malthus predicted that a population growing in geometric progression could not be accompanied in the same proportion by food production, and that this would lead the planet to a supply crisis and famine. For Boserup (1965), intensification of agriculture was an issue of population density and pressure on land use. Several studies have defined empirical and theoretical relationships between demands for land and resources with population dynamics, economy and market globalization (VanWey *et al.* 2005; Mora 2014). Another approach has been proposed by Telecoupling, a logical extension of research on coupled human and natural systems (Liu *et al.* 2013) in which interaction occurs not just within particular geographic locations but also addresses globalized, long distance connectedness made possible by long distance trade markets. These studies aim to develop theories capable of understanding not only human relations with the environment, but also the consequences of these interactions for both parties and for the others indirectly affected.

Land use has the ability to shape landscapes promoting the direct impact on natural resources' conservancy, with consequences for the quality and standards of living, and for the provision and maintenance of ecosystem services (Lambin *et al.* 2003; Foley *et al.* 2005; Pauleit *et al.* 2005; Mahmood *et al.* 2010; Wu *et al.* 2013). Given the importance of forest ecosystems (Ango *et al.* 2014; Fenning 2014) and the dynamic relationship of these ecosystems with the economic, cultural and social dimensions of land use, theoretical and methodological efforts have gone into developing the Forest Transition theory (FT), a theoretical framework to understand the long term trajectories of forest ecosystems.

Explained by two pathways, economic development and forest scarcity (Rudel *et al.* 2005), the FT, as observed in many regions worldwide, has been attributed to similar trajectories of land use, but under different political, social, economic and environmental conditions (Lambin and Meyfroidt 2010; Azevedo *et al.* 2014). The economic pathway assumes that forest regeneration is strongly related to economy, industry and urban development, influencing the process of rural depopulation and the consequent abandonment of the rural way of life, followed by positive, forest growth rates on abandoned areas that had been occupied for agriculture (Rudel *et al.* 2005; Baptista 2008). The scarcity pathway states that forest scarcity can influence institutions at various levels to develop actions of forest recovery in order to restore ecosystem services and to supply timber and non-timber products (Rudel *et al.* 2005; Meyfroidt and Lambin 2009). China and India have already invested in national projects for forest recovery in order to meet the demand for forest products and to address the shortage of this resource after logging cycles (Foster and Rosenzweig 2003; Li 2014).

Evidence emerging from various regions suggests that the quality of forests and biodiversity reflect the influence of past practices on land use (Fairhead and Leach 1995; Spellerberg 1996; Rudel *et al.* 2005; Chazdon 2012). Notably, the legacy of land use and management practices in addition to the prolonged land occupation influence future possibilities for vegetation, especially by the impact on soils and species distribution (Evans and Kelley 2008).

A given forest's history has important implications in understanding forest ecology and the social-political dimensions of human relationships with these ecosystems (Fairhead and Leach 1995). Wright (2010) estimated that 11.8% of tropical forests around the world would regenerate by the end of the 20th century through the process of secondary forest regeneration. This as well as other studies (Chazdon 2012) highlighted secondary forests as important sources of ecosystem services, forest products for communities, and it highlighted the urgent need to understand the underlying forces (biophysical and social) that affect their regeneration after agricultural land abandonment. This research aims to understand: (1) the context that ensures forest regeneration and the control of deforestation over mature forests and secondary succession areas; (2) how public policies, economy, demography, and biophysical landscape are related to the Forest Transition process in the Paraíba Valley, in the Atlantic Forest biome in Brazil.

2. Methods

The methodological approach for data acquisition focused on interviews (structured and semi-structured questionnaires), databases and information (maps and metadata) of land use and land cover changes.

2.1 Study region

Between two mountain ranges, *Serra do Mar* with a maximum elevation of 1877 meters and *Serra da Mantiqueira* with 2791 meters, lies the Paraíba Valley. This valley has an area of 55 thousand km^2 covering parts of the states of São Paulo, Minas Gerais and Rio de Janeiro, within the Atlantic Forest biome. The valley's portion in São Paulo State, of particular interest for this study, consists of 34 municipalities, has an area of approximately 14 thousand km^2, more than two million inhabitants, is an important industrial and economic hub of the State, and represents the upper basin of the Paraíba do Sul river and it is responsible for water supply to a population greater than 10 million inhabitants (Itani *et al.* 2011). The Paraíba Valley is the axis point linking two major metropolitan centers in Brazil (São Paulo and Rio de Janeiro), and for this reason, crossed by a complex road and railway system that runs parallel to the channel of the Paraíba do Sul river. According to Itani *et al.* (2011), the Paraíba Valley region can be divided in to two distinct subregions: the Upper Paraíba Valley and the Middle Paraíba Valley (Figure 3.1). The first subregion consists of more distant municipalities, less developed, less industrialized, farther from the main economic hub of the region (President Dutra Highway) and was excluded from the development policies of the Federal Government from the 1940s to the 1980s. The Middle Valley is made up mainly of industrial areas, services, people and capital with continuous urban areas connected by the President Dutra Highway (Figure 3.1).

Coffee production was the first important economic cycle of the Paraíba Valley, based on monoculture plantations using slave labor. The climate is favorable for coffee and cultivated on newly deforested land, making the region an important center of the Brazilian Empire economy throughout the 19^{th} century. In the later part of the 19th century, the depletion of the soil due to continuous coffee cultivation in the hilly terrain in shallow and poorly structured soils, which favored erosion and loss of the topsoil, compromised soil quality and coffee plantation productivity. This, combined with the expansion of the rail system to the interior of São Paulo State, the arrival of wage labor, and the end of slavery, made this activity less competitive with the coffee that was being produced in the central-west region of São Paulo and this situation led the coffee economy to an overall decline in the Paraíba Valley in the early part of 20th century (Drummond 1997; Zuquim 2007). The decline of the coffee cycle was followed by the emergence of dairy cattle and milk production, which in the 1960s was responsible for 72% of the milk supplied to the city of São Paulo, and with a poorly diversified food production, being primarily intended for domestic consumption in the Paraíba Valley (Eskinazi and Souza 2013).

Between the 1970s and 1980s, dairy farming, the main rural economic activity of the region, declined due to the international economic situation, the end of regulated prices for milk and dairy products by the Brazilian government in 1980, the opening of the economy and the arrival of international dairy companies to compete in the domestic market (Ferreira *et al*. 2006). This scenario re-shaped the sector of milk production in Brazil and in the Paraíba Valley. In the studied region, producers who continued in the dairy business, in most of the cases have adapted to new techniques of pasture management, invested in new cattle breeds, milking machines and cattle semi-confinement, thereby increasing their productivity and ensuring the supply of dairy products.

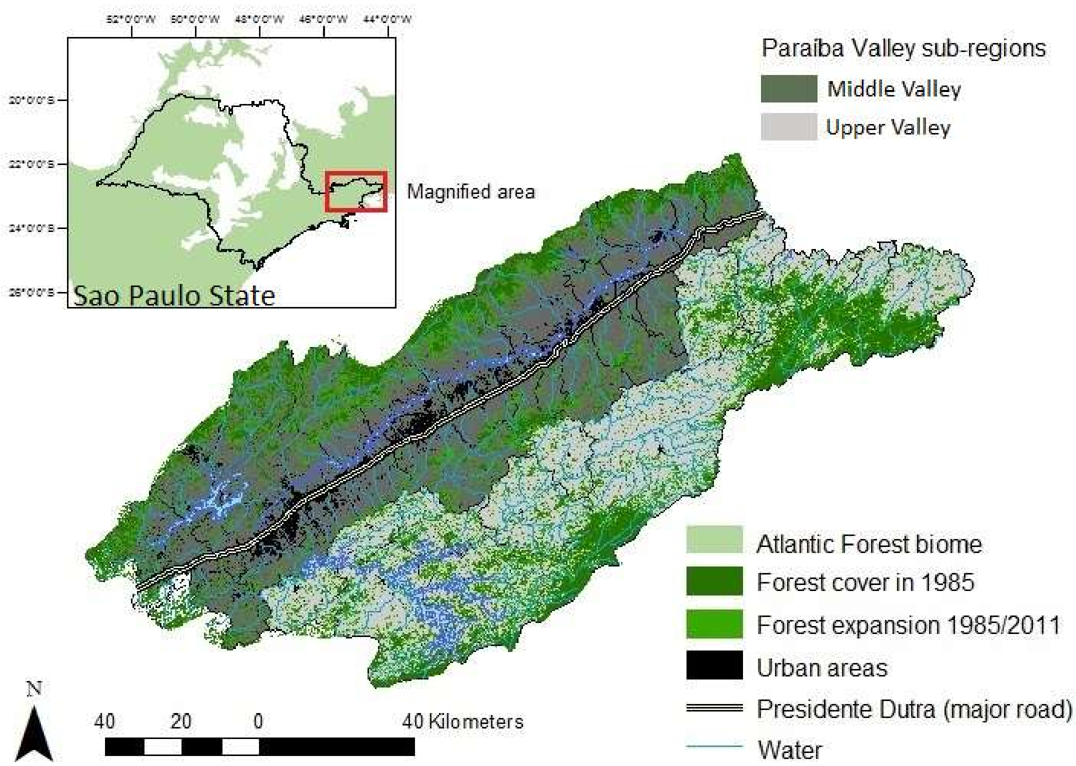

Figure 3.1. Study region. Forest cover information (Capítulo I).

2.2 Qualitative data: interviews

In 2012 and 2013, 17 interviews were conducted in the study region. The interviews were organized in structured and semi-structured questionnaires (4 questions and 12 questions, respectively). Each interview took an average of 80 minutes to complete and was recorded in an audio file. All interviews were applied by the same researcher (RFBS). Before each interview, the interviewer made a short introduction (10 minutes) to contextualize the research and its aims.

Given the extensiveness of the Paraíba Valley region, comprising 34 municipalities and a population exceeding two million inhabitants; after defining the research objectives we conducted a small sample of qualitative interviews with people representing different views. To optimize this procedure, a group of stakeholders with the potential for full participation in the interviews was set. The research considers full participation as a situation in which the interviewee demonstrates enough experience and knowledge to bring necessary contributions to "re-construct" the landscape memories of the Paraíba Valley.

To select the stakeholders, a basic document was used, the *Subsidies for Environmental Planning: Hydrographic Unit Water of Resources Management of Paraíba do Sul* (Itani *et al.* 2011), produced by the Environmental Department of São Paulo State. From the information in this document, people and institutions with potential usefulness were identified to participate of the interviews. As the group identified by the document was interviewed, each interviewee made indications (snowball sampling method) of other stakeholders (people and institutions), which were also heard by the survey. Thus, the responding group was composed of three officials from municipal environmental agencies, a representative of the Department of Water and Energy of São Paulo State (DAEE) and former president of the Committee for the Integration of the Paraíba do Sul Watershed (CEIVAP), two employees from the Chico Mendes Institute for Biodiversity Conservation (ICMBIO), a regional planning assistant from the Integral Technical Assistance Coordination (CATI) region of Guaratinguetá, the director of CATI from the region of Pindamonhangaba, the technical director of the Ecological Corridors Association[7], two researchers from the Oikos Institute[8], two researchers from the National Institute for Space Research (INPE), a historian at the University of São Paulo (USP) – University Campus of Lorena, two farmers, one from Pindamonhangaba and another from the Cunha municipality, both resident in rural areas, and a Sergeant Major of the São Paulo State Environmental Military Police. The ages of this group ranged from 30 to 60 years old with average of 15 years of professional experience in the study region.

[7] http://www.corredorecologico.org.br/index_pc.php
[8] http://www.institutooikos.org.br/

Between September and November of 2014, ninety structured questionnaires were applied in the region to access the farm level. This information will not be used for the present manuscript because its aim is to discuss the regional and subregional level of the Paraíba Valley. A following manuscript will be developed with the farm level information.

2.3 Secondary data

The study used internet sites, newspapers, scientific journals, historical documents and socioeconomic statistics provided by government research institutes. From the recovery of secondary data and information about land use/cover and growth rates of forest (Capítulo I), comparative and statistical analyses were performed. Given the complexity and heterogeneity of the study area related to the aspects of industrialization, urbanization, population dynamics and biophysical aspects of the landscape, the dataset was analyzed at regional (Paraíba Valley) and subregional (Upper Valley and Middle Valley) levels.

3. Results and discussion

3.1 Socioeconomic dynamics and land use

The Paraíba Valley's land use is composed by a matrix of pastures, urban areas concentrated in the road axis (mainly following the President Dutra Highway) that connects the capital cities of São Paulo and Rio de Janeiro, eucalyptus forest plantation covering less than 10% of the region, agricultural areas (mainly rice) in the floodplains of the Paraíba do Sul river and forest cover consisting of numerous fragments scattered across the countryside and totaling 32% of the Paraíba Valley of São Paulo State.

The rural population of Paraíba Valley, 5.81% in 2010 (132 thousand inhabitants) held 1.83% of formal jobs compared 98.17% in the industry, commerce and services sectors. The rapid expansion of industry and services in the Paraíba Valley, since the 1950s, created an intense migration flow from the countryside to urban areas (Bordo 2005) and from poorer municipalities to the major economic and industrial centers of the region (Vieira and Santos 2012). The industrialization process of the region, since 1891, has intensified since the 1950s due to the entry of foreign and State investments, construction of the President Dutra Highway (connecting São

Paulo and Rio de Janeiro), the creation of the technological center of the aerospace industry, Federal initiatives oriented to the basic sectors of industrial economy, and industrial decentralization in São Paulo State, with consequent rural depopulation and a rapid urban population growth (Boffi *et al.* 2006; Vieira and Santos 2012). In the 1960s Paraíba Valley was considered one of the main industrial centers of Brazil (Vieira and Santos 2012). A population census by the Brazilian Institute of Geography and Statistics (IBGE) showed a sharp decrease in the rural population followed by urbanization between 1950 and 2010, while in the subregions the population dynamics did not follow the same trend (Figure 3.2).

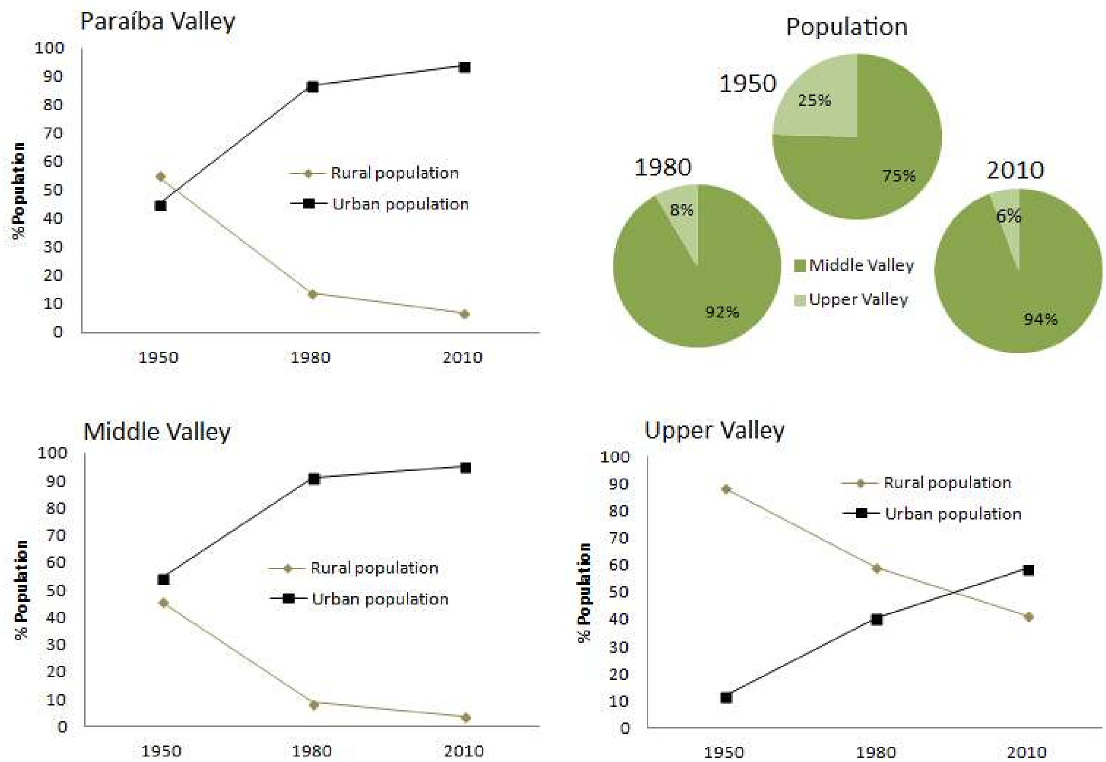

Figure 3.2. Population dynamics of the Paraíba Valley, São Paulo State (IBGE, population census < http://www.censo2010.ibge.gov.br/sinopse/index.php?dados=8>).

Figure 3.2 reveals the complexity in the population dynamics of the Paraíba Valley when the region is analyzed at different levels. According to the stakeholders interviewed, the process of industrialization exerted influence on the rural exodus and internal migration flows from the less economically developed regions to the more developed, as noted by Viera and Santos (2012). The relationship between the Middle and Upper Valley since the 1950s is marked by a considerable inequality in the distribution of services, income and job opportunities, which were decisive factors for the population dynamics of the subregions. While the Upper Valley had population growth rate of 0.0036% between 1950 and 2010, in the Middle Valley it was 452%.

From the land use and land cover information we observed that there has been an increase in forest cover since 1962, with the highest growth rate seen in the period of 1985 to 1995 (Figure 3.3). According to Boffi *et al.* (2006), the 1980s was the consolidation period of the technological and industrial sectors in the Paraíba Valley, when the region's urban population was 86%. At that time, the Middle Valley concentrated 92% of the region´s urban population and 94% of the region's industrial, commerce and service establishments. Thus, the reading of the forest transition process is observed from two perspectives: (1) Paraíba Valley or region; (2) subregions (Upper and Middle Valley).

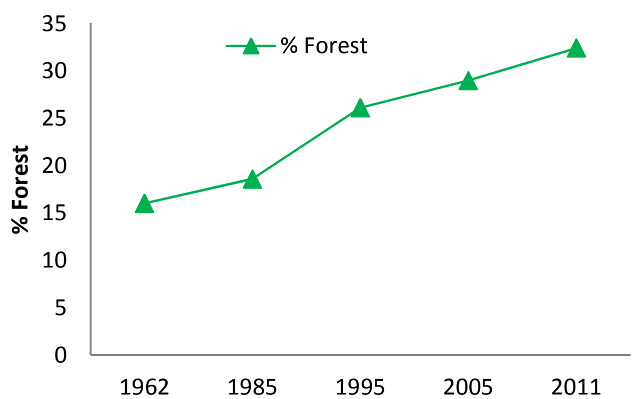

Figure 3.3. Dynamic of forest cover in the Paraíba Valley, São Paulo State (Borgonovi et al., 1967; Capítulo I).

3.1.1 Paraíba Valley region

The native Atlantic forest cover described in Figure 3.3 showed an increase of 102% in forest vegetation between 1962 and 2011. The second half of the 20th century and the early 21th century highlighted the relationship between the rural exodus in the Paraíba Valley, industrialization, economic development, the rural socioeconomic crisis (especially in dairy farming), with consequent rural depopulation followed by forest regeneration on abandoned pastures in mountainous regions (Capítulo II), consistent with forest transition patterns observed in Latin America (Aide and Grau 2004; Mather and Needle 1998). The multi-temporal analysis showed a strong positive correlation between economic development and forest cover during the period of 1985 to 2011. (Figures 3.4a, 3.4c, 3.4d).

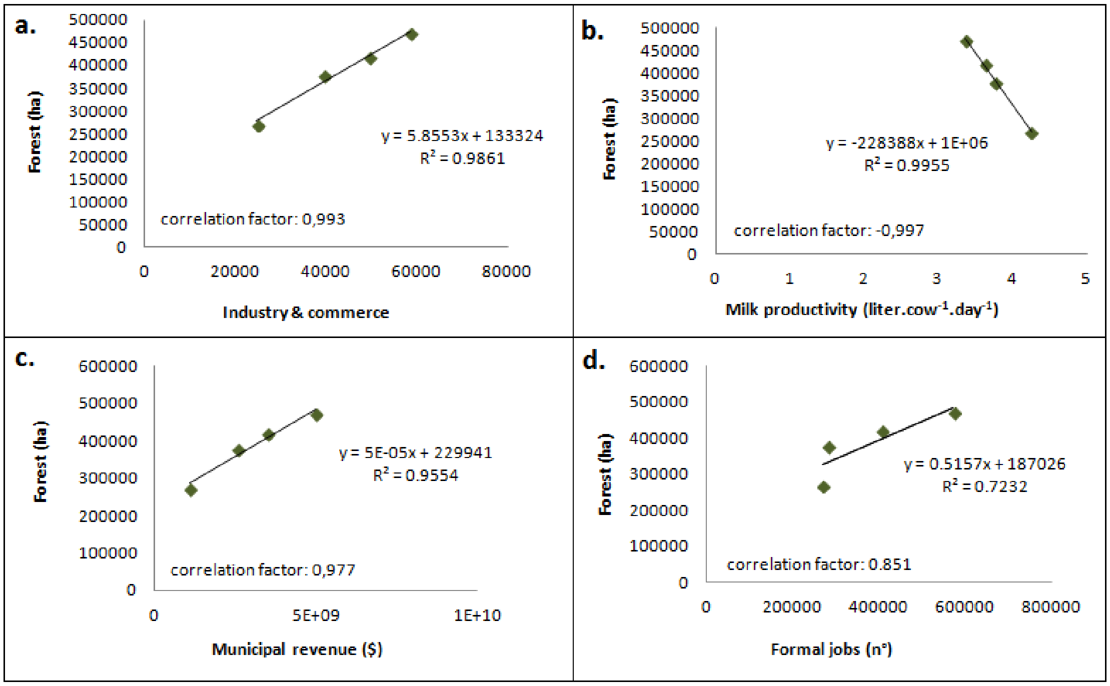

Figure 3.4. Linear regression and correlation analysis between the dynamics of economy and milk productivity of Paraíba Valley with temporal forest cover data. Years of analysis – 1985, 1995, 2005 and 2011. Forest cover data (Capítulo I). Socioeconomic dataset (Foundation State System of Data analysis – SEADE < http://www.seade.gov.br/>).

The correlation factor (Figures 3.4a, 3.4c, 3.4d) indicates that while changes have occurred in the economic structure of the Paraíba Valley, increases in forest cover were also observed, suggesting the economic development pathway of the FT theory (Rudel *et al.* 2005). However, these relationships may not be sufficient to explain the observed increases in forest cover since the generalized characteristic of this theory may miss important explanations of specific contexts that are behind the economic development (Perz 2007). The relationship between forest cover and milk productivity (Figure 3.4b) supports the views of the interviewed group. They credit the drop in milk production to the falling prices and the loss of pasture productivity, caused by land degradation and overgrazing, forcing many farmers to abandon this activity or decrease their scale, with a consequent abandonment of pasturelands followed by the return of natural vegetation. This abandonment of land followed by the increase of forest vegetation was observed mainly on steep slopes (over 20%), aspect orientation to the geographical South and regions further from paved roads (Capítulo II). In 2011 77% of forest cover in the Paraíba Valley was concentrated on slopes over 20%. The analysis of the results from the economic indicators with forest cover (Figure 3.4.a, 3.4.c, 3.4.d) challenges the conservationist paradigm of the negative effect of economic growth on the forest ecosystems, as argued by Aide and Grau (2004).

3.1.2 Subregions

The subregional analysis of forest cover presented an unequal relationship between concentration of the Atlantic Forest remnants in the Upper and Middle Valley (Table 3.1). From the interviews, this relationship has already been reported, since, after the coffee cycle, the municipalities of the region who had not integrated to the industrial and urban development cycle, faced severe processes of outmigration and economic stagnation during the first half the 20th century. Consequences of these events was less pressure on the remaining forests in the Upper Valley after the coffee cycle, the lesser populated subregion, farther from economic centers and highways, with a predominance of subsistence agriculture and family farming (Zuquim 2007). In 1975 the cattle herd in the Middle Valley totaled 341 thousand animals or 55% of the Paraíba Valley's cattle herd, accounting for 63% of the milk production (PPM/IBGE 1975), farm sizes are on average larger than in the Upper Valley (Eskinazi and Souza 2013).

Table 3.1. Percentages of forest cover distributed in the subregions of Paraíba Valley, considering the total (100%) of forest vegetation for each year (Borgonovi *et al.* 1967; Capítulo I).

	Forest cover distributed in the subregions (%)	
Year	Upper Valley	Middle Valley
1962	62.31	37.69
1985	59.32	40.68
1995	57.43	42.57
2005	58.14	41.86
2011	55.64	44.36

The observed results (Table 3.1) showed a tendency of equating the rates of forest cover between the subregions and the highest pressure exerted on forests was in the Middle Valley subregion until the 1960s, when the percent of forest cover was 11.39% while the Upper Valley 20.73%. This data suggests that socioeconomic context of rural areas in the subregions had a decisive role in the rates of forest cover observed in 1962, when the lowest rate of forest cover (11.39%), observed in the

Middle Valley, reflected the highest pressure on land use in this subregion until the 1960s, already suggested by the interviewees and Zuquim (2007).

From the second half of the 20th century, the trajectory of forest cover shifted, especially in the Middle Valley, which had a 133.34% increase between 1962 and 2011. The Upper Valley had a 77.13% increase in the same period. Between 1975 and 1995, the growth rate of the cattle herd in the Paraíba Valley was negative (-24%) and also in the Middle Valley was -27% (PPM/IBGE 1975; PPM/IBGE 1995). Livestock, an important economic activity of the Paraíba Valley (Sachs *et al.* 2006) occupied approximately 65% of land use (pastures) in 1985 (Capítulo I). During the period of 1962 to 1995, the highest rates of forest increase were also observed, 81% in the Middle Valley and 48% in the Upper Valley. High levels of economic development of the Middle Valley accompanied by significant reduction in livestock pressure between 1975 and 1995 suggest that in this subregion the combined effect of these variables had more influence on the forest's regeneration process, compared to the Upper Valley. The Upper Valley had lower rates of livestock, a smaller rural exodus and increases in economic stagnation, accompanied by lower rates of forest regeneration. The confrontation between economic development, industrialization, population dynamics, livestock (cattle herd) and forest cover data for both subregions, corroborated field work evidence about the impact of socioeconomic changes on the land use and land cover dynamics.

3.2 Land Use

3.2.1 Functional loss of agricultural landscape

Functional loss of the agricultural landscape is defined as the process of retraction or a decrease of agricultural land use replaced by secondary forest succession that results from land abandonment in formerly agricultural areas. As the rural population migrated to urban areas searching for employment, better income and better living conditions, there was decrease in the availability of labor for agricultural activities in the Paraíba Valley. Labor activities were characterized by low technology and intense demand for manual labor in a landscape dominated by steep slopes (63% of Paraíba Valley has slopes of over 20%). The low availability of labor for agricultural jobs in the region is a problem recognized by the interviewed group and represents a challenge to the success and maintenance of agricultural production units which persist in the region. Between 1995 and 2011, the Paraíba Valley faced a decrease of

37% in production (tons) of agricultural products with reduction of 44% in land crop areas (PAM/IBGE 1995; PAM/IBGE 2011). In the subregional analysis, the Upper Valley had decreased 66% of their acreage while in the Middle Valley, the reduction was 32%. The highest rate of decline observed in the Upper Valley coincides with the period of inversion from a predominantly rural population to an urban one (Figure 3.2).

Land use and land cover dynamics reveal a decrease in areas occupied by degraded pastures (characterized by the appearance of erosion, growth of grasses and shrubs in competition with pastures) replaced by secondary forests, managed pastures and planted eucalyptus forest (Figure 3.5). These trends indicate that the functional loss of the agricultural landscape can boost the process of forest regeneration over areas previously used for agricultural purposes.

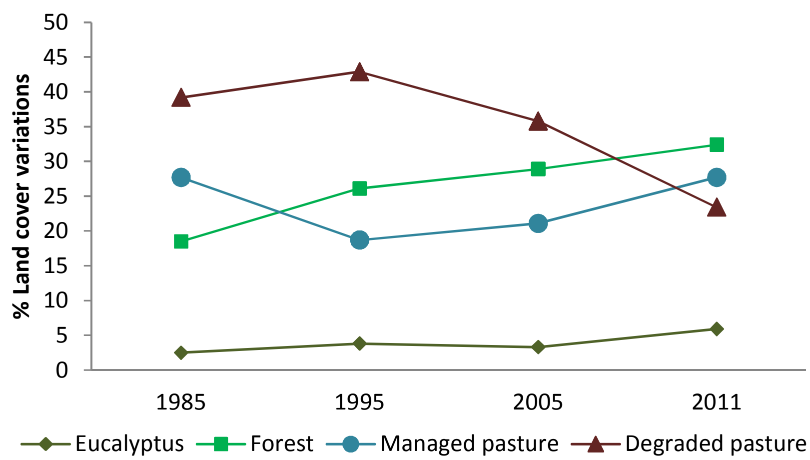

Figure 3.5. Variation rates of land use and land cover classes in the Paraíba Valley, São Paulo State (Capítulo I).

Concerning the agricultural landscape of the Paraíba Valley, it is evident that the forest regeneration process is related to the characteristics of relief, consisting of steep slopes or *seas of hills* (Ab'Saber 2003). The intersection between land cover data and relief showed that 73% of new forest areas occurred on slopes of over 20%, representing areas unsuitable for agricultural mechanization, irrigation systems (e.g., center pivot irrigation) or livestock (Lepsch *et al.* 1991; Andrade 2001). Approximately 60% of the forest regeneration occurred In the south face of the relief (aspect orientation). This aspect orientation of the Southern Hemisphere represents less sunny surfaces hence less suitable for agricultural uses (Rosenberg *et al.* 1983; Bale *et al.* 1998; Mello 2009). From the institutional perspective of the rural extension agencies, the terrain characteristics allied with unsuitable management practices in depleted soils cultivated over a century without sustainable practices, and low technology, contributed to the loss of soil productivity for agriculture and livestock, thus structuring a scenario of economic crisis in the rural economy boosting rural depopulation and land use abandonment.

3.2.2 Eucalyptus planted forest

The eucalyptus produced in the region is predominantly used for the production of pulp and paper. Eucalyptus plantations had strong incentives in the region during the 1980s, with the creation of the first course regarding integration of the pulp and paper industries funded by the National Bank for Social Development (BNDS) in 1980, and the founding of *Votorantim Papel e Celulose* (VCP) in 1987, in the municipality of Jacarei, in the Middle Valley. This land use class in 1985 represented 2.58% of the Valley and was distributed between the Upper Valley with 51.36% and Middle Valley with 48.64%. In 2011 eucalyptus plantations increased to 6.15% and were distributed in the proportions of 58.17% in the Upper Valley and 41.83% in the Middle. The growth rate of area in eucalyptus between 1985 and 2011 was 167.31% in the Upper Valley and 102.96% in the Middle Valley.

Mapping data from 1962 (Borgonovi *et al.* 1967) present Paraíba Valley with less than 1% of eucalyptus planted forests concentrated only in the Middle Valley, near the municipalities of Pindamonhangaba and Jacarei, the only two with pulp and paper industries in the region. To explain the reversal in eucalyptus coverage rates between the subregions, the informants reported that eucalyptus expansion prioritized cost-benefit opportunities taking into account land price and distance of plantations in relation to the industries. In this case the highest rate of expansion was observed closer to industries and in the Upper Valley where the devaluation of land prices as a function of the distances to economic centers and urban areas was greater. During the introduction of industrial-scale eucalyptus plantations in the region since 1970 (Eskinazi and Souza 2013), the Valley faced its crisis in dairy farming (Ferreira *et al.* 2006; Eskinazi and Souza 2013). This scenario opened opportunities for eucalyptus. Among the thirteen municipalities of the Upper Valley, six municipalities (Jambeiro, Natividade da Serra, Paraibuna, Redenção da Serra, Santa Branca and São Luís do Paraitinga) located near the pulp and paper industries, in the Middle Valley (Jacarei and Pindamonhangaba), accounted for 53.8% of the eucalyptus expansion in the Valley with a 197% growth rate between 1985 and 2011.

While the Paraíba Valley presented an increase of 9% in milk production between 1975 and 2012, the six municipalities (Upper Valley) with highest growth rate of eucalyptus plantation had declining milk production (-36%) (PPM/IBGE 1975; PPM/IBGE 2012). This data suggests that where there was expansion of eucalyptus, there was a decline of traditional agricultural activities in the region, most notably dairy farming, a relationship already observed by Eskinazi and Souza (2013).

Land use and land cover dynamics of the Paraíba Valley (Capítulo I) revealed eucalyptus's contribution to deforestation rates as being between 0.5% to 1.0% in relation to the growth of the region. However, a positive relationship between this land use and forest transition was expected. As the commercial eucalyptus plantations (destined for pulp production) is set in farmland, a minimum area of the farm (20%) shall be allocated for native forests, a legal requirement under the Forest Code for all rural properties in the Atlantic Forest biome (Law n^0 12.651 of Brazil 2012).

The compliance with this standard, as required by the law, as pointed out by other studies (Farinaci *et al.* 2013) by representatives of the forestry sector and public institutions of rural extension and management of protected areas, is due to the demands of certification seals from the Forest Stewardship Council (FSC) and the Brazilian Forest Certification Program (Cerflor), which are required to trade pulp in international markets. Approximately 89% of pulp produced in the Paraíba Valley is sold in European and Chinese markets (Brandão 2012). Between 1985 and 2011, the region composed by the six municipalities of the Upper Valley mentioned previously, had a forest cover growth rate of 77% while for the other municipalities in the same subregion it was only 58%, which indicates a higher increase of forest cover in the eucalyptus producing regions.

The Globalization pathway, a more modern version of the economic development pathway occurs when a national economy becomes increasingly integrated into global markets for commodities, labor, capital, tourism and ideas (Rudel 2002). Economic globalization also facilitates the displacement of deforestation from countries that undergo a forest transition to forest-rich regions, via the international timber trade (Lambin and Meyfroidt 2010) as noted in the Paraíba Valley eucalyptus producer region.

3.2.3 Land use intensification

While on one hand agricultural land use abandonment contributed to the increase of forest cover, on the other hand, agricultural intensification can result in positive effects for native vegetation, since productivity increases per unit/area have been observed when reducing pressure on forest remnants and the opening of new production areas (Tilman *et al.* 2011). At this point, two important economic activities in the rural Paraíba Valley, eucalyptus plantations and dairy farming, intensified. In 1968 the average of eucalyptus productivity was 17.5m³/hectare/year increasing to 48m³/hectare/year in 2000 (Montebello and Bacha 2009). For the Paraíba Valley cattle herds, the stocking rate between 1985 and 2011 changed from 0.4 to 0.9 animals/hectare, reaching 1.5 animals/hectare when only considering managed pastures (Capítulo I).

Since 1962 the forest cover kept increasing until the end of the time series in 2011 (Figure 3.3). This information indicates that even with the increase of stocking rate and eucalyptus plantations, there was no stagnation in the process of forest regeneration. Thus, the hypothesis that intensification can reduce pressure on the demand for productive areas (Tilman *et al.* 2011), found evidence in the Paraíba Valley, where agricultural intensification made it possible for the economic exploitation of agricultural land without interrupting the process of forest regeneration.

3.3 Public policies and social engagement

The Atlantic Forest biome was the first to go through the process of deforestation and changes in their natural ecosystems, since European colonization of Brazil. The first five centuries of Brazilian colonization led the Atlantic Forest to a decrease of approximately 92% of its original size, which sparked alarm in the environmental community, public officials, politicians and institutions. An important response to this crisis was the Federal Constitution of 1988 (Article 225), which recognized the Atlantic Forest biome as a national heritage site and resulted in the drafting of specific laws for its management and conservation. After the promulgation of the Federal Constitution (1988), the Federal Government, without the participation of State Governments covered by this biome, nor experts from environmental and civil society, issued Decree n^0 99.547 (1990) that banned the cutting and exploitation of the native Atlantic Forest vegetation, but did not define its legal boundaries and the vegetation characteristics of the biome, and did not create guarantees to protect disturbed forest remnants and areas that are in the process of secondary forest succession (Lima and Capobianco 1997).

In response to this scenario, the National Environmental Council (CONAMA), represented by legislators, environmental experts and governmental and non-governmental organizations met to draw up a new proposal, one more adequate for the urgent needs of the biome. These efforts culminated with the approval of Federal Decree n^0 750 (1993). This decree considered the fact of this biome in the early 1990s, being in one of the most developed states of Brazil, housing more than 60% of the Brazilian population; hence, recognizing the challenges of the Atlantic Forest conservation in a populated and developed region. The progress made by this decree assured the definition of the Atlantic Forest domain and set all forest formations and ecosystems associated to its domain, besides the recognition of disturbed remnants and secondary forest succession in both early and advanced stages, as part of the vegetation, and thus their protection under the law. In 2006 the Federal Government approved the Law n^0 11.428 (Atlantic Forest Law) which represents the legal instrument to protect the biome, and it is also regulated by the Federal Decree n^0 6.660 of 2008 which does what?.

The formulation of public policies for the conservation and protection of the Atlantic Forest biome, since 1993 (Decree n^0 750), shows concern with the recovery of this biome and not just with the conservation of its remnants, which in the FT perspective suggests the scarcity pathway (Rudel *et al.* 2005; Lambin and Meyfroidt 2010), since in the 1980s approximately only 8% of its natural vegetation remained (Fundação SOS Mata Atlântica /INPE 2011). The concern with the biome's recovery is evident in Article 36 of the Atlantic Forest Law, which instituted an economic plan of incentives for its recovery.

3.3.1 Protected areas (Conservation units)

The Brazilian National System of Conservation Units (SNUC, Federal Law n^0 9.985 of 2000) has an important role in the management and conservation of biomes. According to experts from the Chico Mendes Institute for Biodiversity Conservation (ICMBIO), the institution has expanded its activities in monitoring and ensuring compliance with the rules required by SNUC within protected areas.

The Paraíba Valley has approximately 444 thousand hectares (30% of the Paraíba Valley total area) in Conservation Units (CU), distributed between two categories: full protection and sustainable use. This CU network has been established since 1960 (Decree n^0 36.771 - Creation of Taubaté Forest Nursery), and around 80% of the CU in the region were created from the 1980s (Itani *et al.* 2011). The full protection CU does not allow land use and occupation. In these areas only recreational activities, eco-tourism and research are allowed. The sustainable use category allows for land use and occupation with restrictions in accordance with the management plan, which represents the manual of use and responsibilities that society should follow within the CU. According to the document *Subsidies for Environmental Planning* (Itani *et al.* 2011), of the twenty two conservation units (six of full protection, sixteen of sustainable use) in the Paraíba Valley, only six have a management plan, four in the sustainable use category. Between 1985 and 2011 there was a continuous growth rate of forest cover within the conservation units of the Paraíba Valley (Table 3.2).

Table 3.2. Forest cover dynamics within conservation units. Forest cover data (Capítulo I).

	Forest Cover Within Conservation Units (%)	
Year	Full Protection	Sustainable Use
1985	65.51	13.19
1995	77.71	32.03
2005	83.96	36.28
2011	86.11	40.67

The smaller proportion of forest vegetation cover in the CU of sustainable use is an expected result, since there are areas where land use and occupation are allowed, but with severe restrictions on vegetation removal and rates of soil impermeabilization. From this perspective, deforestation rates in the CU of full protection decreased from 6.96% in 1985/1995 to 2.37% in 2005/2011, while in the CU of sustainable use, the decrease was 4.16% to 3.46% for the same periods. Deforestation rates in the CU are associated to public infrastructure projects, such as the construction and expansion of roads, energy infrastructure and logistics, and illegal human occupation.

3.3.2 Environmental structure for deforestation control

Governance at all levels is important for reducing deforestation and encouraging programs of forest recovery (Farinaci 2012). Subordinate to the Military Police of São Paulo State and a branch of the Environmental System of São Paulo

State, the Environmental Military Police[9] (EMP) is the institution responsible for enforcing environmental legislation in São Paulo State, with powers to prosecute any actions that represent an *environmental crime* (e.g.,, hunting, deforestation, use of fire, trafficking of animals). The EMP in São Paulo State had its origin in the Forest Service (year of 1943), a branch institution subordinated to the State Department of Agriculture. In 1949, due to the environmental protection activities, the State Department of Agriculture asked the State Government to create a police corporation from the Security Forces; thus the protection service of environmental and natural resources became the responsibility of the Military Police, called the Forest Police. The institutional link between the environmental police service and the State Department of Agriculture has created conflicts of interest and undermined the effectiveness of the forest protection service, as appears in the testimony of the EMP informant:

"At the time, the Forest Police worked subordinately to the State Department of Agriculture, but did not achieve the desired results and their objectives were in conflict, because the State Department of Agriculture was acting in order to remove the native vegetation to expand agriculture. In an opposite sense, the Forest Police likewise had a duty to prevent the removal of this native vegetation. Another deteriorating factor that prevented the Forest Police from working effectively was the fact that the available legislation was not about preserving the environment with caution and with a scientific basis, since the priorities of the time were directed to urban and industrial development. The inadequacy of legislation propitiated stimuli to practices of offenses against the natural environment".

The solution to this situation came in 1986 with the creation of the State Department of the Environment, which assumed the responsibilities for the guidance of the environmental police service:

"...thus, allowing the performance of the Forest Police embedded of legal basements and in accordance with federal law, making ostensible, preventive and repressive policing to protect the natural resources".

[9] Denomination created in 2001 by the State Decree n^0 46.263.

In the Paraíba Valley, the environmental police service was established in 1975 in Taubaté (Middle Valley). From the perspective of the EMP informant interviewed, in Brazil there is a need for supervisory institutions to ensure compliance with laws and social norms, which justify the need for environmental policing to ensure environmental law enforcement. After the creation of the State Department of the Environment in 1986 and the formalization of joint actions between this institution and the State Department of Public Safety, the idea for the necessity of an ostensive and preventive police service to ensure environmental protection was consolidated (Ramos 2011).

From an EMP dataset between 2003 and 2013, for the Paraíba Valley, there were 9570 reports of environmental violations of which 61% were for illegal deforestation. Between 2003 and 2013 the region had an annual average of 587 deforestation offenses, despite a decline in the extent (hectares) of areas affected by deforestation or degradation of natural vegetation (Figure 3.6).

The dataset reveals a non-existent relation between the number of environmental violation notices with the extent (hectares) of areas affected by deforestation, since, even with constant average rate of offenses, the extent of areas suffered a reduction of 429% over this period.

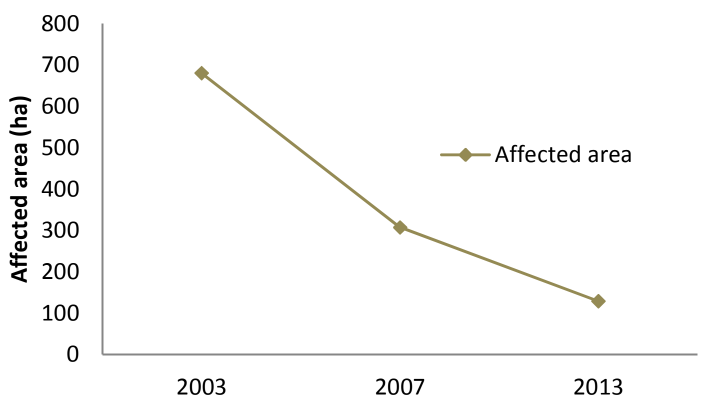

Figure 3.6. Total areas (hectare) affected by deforestation. Source: Environmental Military Police of São Paulo State.

The impact of the Federal Decree (n^0 750 of 1993) and the Atlantic Forest Law (n^0 11.428 of 2006) on the process of forest regeneration is evident by the EMP surveillance results, which reveals that 95% of the offenses were related to deforestation actions, and they corresponded to areas with vegetation in early stages of secondary forest succession. Human pressure on natural vegetation in recent years has focused on lands in the processes of secondary succession, responsible for the positive growth rates of forest cover. The Paraíba Valley forest cover in 2011 was composed by 41% of primary vegetation or in advanced stages of succession and 59% by early stages of secondary succession (Capítulo I). In 1995, two years after the approval of the Federal Decree (n^0 750 of 1993), 71% of Paraíba Valley forest cover was primary vegetation or in advanced stages of succession, while 29% was early stages of secondary succession. The untouchableness of the native vegetation in the process of secondary succession, guaranteed by the Federal Decree n^0 750, was strategic in favoring the positive growth rates of forest cover in the Atlantic Forest biome, because they represent the forest formations where there is greater human pressure, thus justifying the need for their protection as a guarantee to the forest transition process. From the FT theory perspective, the strategy of this policy was guided by the scarcity of Atlantic Forest remnants.

In 1988 The State Law n^0 6.171 (Law of agricultural soil conservation and use) was approved, which banned the use of fire as a land management practice. This act, according to the CATI employees, played an important role in the processes of forest regeneration, especially in mountainous areas and regions less suitable for agriculture. Once the practice of burning became prohibited; the maintenance of pastures began to be performed manually, as can be seen in the photograph below (Figure 3.7).

Figure 3.7. The photograph (recorded in 2012) shows a farmer doing the pasture maintenance (cleaning of dirty pasture), manually. Until 1988, the cleaning of dirty pasture was made predominately by the use of fire, which dispensed hand labor and avoided native vegetation growth in larger areas compared with the extension kept by manual weeding by sickle, as seen in the image.

In the period after State Law n^0 6.171, farmers realized that the cost-benefit of maintaining pastures was not positive, especially where there were degraded soils, steep slopes, and slopes on southern hemisphere relief faces (opposite-faces), less appropriate for dairy farming. Thus, many areas were abandoned with the consequent regrowth of secondary forest succession. According to one of the CATI employees, the environmental police service was critical to ensure compliance with the law, prohibiting the use of fire as an agricultural management practice.

From 2003 (data from EMP) until 2013, the number of fires in the Paraíba Valley fell from 46 to 6 cases per year. Even in a short time period (10 years), this data presented a decreasing tendency for the use of fire as an agricultural practice. The importance of controlling anthropogenic fires for forest regeneration has been observed in a conservation area in Costa Rica. Twenty years after the adoption of controlling anthropogenic fires, seed dispersal from forest fragments in a landscape dominated by pastures on highly degraded soils, became young forests (Janzen 2002).

3.3.3 Society and public policy management

Government institutions are not the only actors involved in the process of environmental improvement (Farinaci 2012). In recent decades it has been observed that, especially since the 1970s, after the World Environmental Conferences, from Stockholm in 1972 to Rio+20 in 2012, a significant increase in the participation of society on the process of environmental monitoring, control and conservation (Cunha *et al.* 2013). For Brazil, the approval of Agenda 21 [10] after the United Nations Conference on Environment and Development (Earth Summit – Rio 92), there was an increase in the number of non-governmental organizations (NGOs) with the mission of environmental preservation, environmental education projects and campaigns, as well as the approval of the National Environmental Education Police (Law n^0 9.975 of 1999) and the Law of Environmental Crimes (Law n^0 9.605 of 1998 – Law of Nature).

Acknowledged by the EMP, surveillance and environmental law enforcement in São Paulo State is a result of the voluntary participation of a society that through the Environmental Ombudsman[11] informs the Environmental System of São Paulo State about offending acts, in the form of citizens denouncing individuals for environmental crimes. The engagement of society in environmental law enforcement is observed in the Environmental Ombudsman reports[12]. The institution of the Environmental System that receives more demands of society is the EMP, and for cases of natural vegetation suppression or suspected deforestation. Between 2003 and 2013, 63% of notices made to the EMP were to investigate potential crimes of vegetation suppression or suspected deforestation.

Field observations revealed that the rural population of the Paraíba Valley has concerns about the punishment applied by environmental law enforcement in cases of environmental crimes. The cause of this concern is related to the fear caused by environmental infractions that drives surveillance of EMP to investigate each one and may cause fines, imprisonment, and the embargo of the area in which the environmental crime occurred for an indefinite period. According to the EMP informant, the embargoed areas, after some years had changed from degraded areas into forest

[10] Instrument of planning to build sustainable societies, in different geographic bases, which combine methods of environmental protection, social justice and economic efficiency. Source: http://www.mma.gov.br/responsabilidade-socioambiental/agenda 21.

[11] Founded in 1993, the Environmental Ombudsman is a central communication between the population and the state government, in order to facilitate complaints and reports regarding any acts that disrespect citizenship rights and strengthen democracy. Source: http://www.ambiente.sp.gov.br/a-secretaria/ouvidoria/

[12] http://www.ambiente.sp.gov.br/a-secretaria/ouvidoria/prestacao-de-contas/

vegetation. The concern with environmental complaint is clear in the speech of a rural resident from the municipality of Cunha, Upper Valley:

"Because the environmental legislation nowadays, after the bush begins to grow you cannot clear the area. So, where have this kind of dirty pastures and you leave the bush come back, nobody else can suppress and change to other land use. If you clean the bush someone complaint and the surveillance (EMP) may appear".

The changes in behaviour due to the perception of the Environmental System functioning in São Paulo State is also expressed by Figure 3.6, which shows the decrease in extension of affected areas by deforestation or degradation of natural vegetation. This scenario suggests the emergence of a precautionary behavior in order to avoid environmental crimes, because there is the perception of the risk of environmental complaint followed by the EMP's surveillance, with potential law enforcement that may bring juridical and financial consequences provided by the "Law of Nature".

4. Conclusions

Although there are two generic pathways towards Forest Transition, the economic development and the forest scarcity paths, there are many contexts that shape the FT model that are observed in each particular region. This means that even if the socioeconomic changes from a specific region (e.g., rural exodus, industrialization) are influential variables for this process, local features such as relief, historical land use and land cover, public policy, the engagement of the society to ensure law enforcement, international markets in globalized economies, and the action of enforcement agencies, represent dimensions, which combined, can create favorable contexts for forest regeneration.

Deforestation control, a basic requirement for the FT, cannot be assumed as the only necessary condition for this process, but rather, an essential condition to ensure that the forest regeneration, through the emergence of areas in secondary forest succession, be maintained in the landscape without a replacement by other land uses (e.g., pastures, urban areas, eucalyptus). Thus, the legal mechanisms to protect the Atlantic Forest biome have contributed positively to the increase of forest cover in the Paraíba Valley, since degraded areas experiencing regeneration processes are considered as part of the forest biome and subject to protection.

The control of deforestation and the increase of forest cover areas, two key elements of the FT, are connected in a regional arrangement and influenced by endogenous and exogenous variables of the Paraíba Valley. These variables act at different periods over time, thus creating the necessary conditions for forest regeneration in the Atlantic Forest biome.

As endogenous variables, there lies the disinterest about the rural way of life in the region, motivated by the degradation and loss of production capacity of the agricultural landscape, employment opportunities and better living conditions in urban centers, industrialization, economic development, plus the topographical landscape (seas of hills), which discourages the establishment of mechanized, irrigated and large-scale agriculture. As the increase of forest cover begins, documented since 1962, exogenous variables begin to interact with the FT process in the Paraíba Valley. These variables include public policy, economic development, the service of governmental agencies to protect the environment, and the engagement of civil society. These exogenous variables play an important role in ensuring the development of areas in secondary forest succession and the conservation of the remnants of native vegetation. Among the exogenous variables are the forest certification seals, which, linked to the international marketing of pulp, exert an influence on the decision to ensure 20% of the farms with forest remnants of Atlantic Forest biome, thus favoring the FT process as the eucalyptus produced in the Paraíba Valley is mainly sold as pulp in international markets.

References

Ab'Saber, Aziz Nacib (2003). Os domínios de natureza no Brasil: potencialidades paisagísticas [The Natural Areas of Brazil: landscape potentialities]. São Paulo: Ateliê Editorial, 6ªed.

Aide, T. M., Grau, H. R. (2004). Globalization, migration, and Latin American ecosystems. Science 305(5692): 1915–1916.

Andrade, C. L. T. (2001). Seleção do Sistema de Irrigação [Selection of Irrigation Systems]. Sete Lagoas: MAPA.

Ango, T. G., Borjeson, L., Senbeta, F., Hylander, K. (2014). Balancing Ecosystem Services and Disservices: Smallholder Farmers' Use and Management of Forest and Trees in an Agricultural Landscape in Southwestern Ethiopia. Ecology and Society 19(1).

Azevedo, J. C., Perera, A. H., Pinto, M. A., eds. (2014). Forest Landscapes and Global Change: Challenges for Research and Management. New York, Heidelberg, Dordrecht, London: Springer.

Bale, C. L., Williams, J. B., Charley, C. L. (1998). The impact of aspect on forest structure and floristics in some Eastern Australian sites. Forest Ecology and Management 110(1-3): 363–377.

Baptista, S. R. (2008). Metropolitanization and Forest Recovery in Southern Brazil: a Multiscale Analysis of the Florianópolis City-Region, Santa Catarina State, 1970 to 2005. Ecology and Society 13(2).

Boffi, S. A. N. O., Ricci, F., Oliveira, E. A. A. Q. (2006). Análise histórica da região do Vale do Paraíba como atrativo para a implantação da indústria de base (1930 - 1980) [Historical analysis of the Paraíba Valley region as attractive to the development of basic industry]. Revista Univap 13(24): 3059–3063.

Bordo, A. A. (2005). Os Eixos de Desenvolvimento e a Estruturação Urbano-Industrial do Estado de São Paulo, Brasil [The Axis of Urban-Industry Development and Organization in the São Paulo State, Brazil]. Scripta Nova 194(79): 741–798.

Borgonovi, M., Chiarini, J. V., Amaral, A. Z., Coelho, G. S., Oliveira, D. A. (1967). Cobertura Vegetal do Estado de São Paulo [Vegetal Cover of São Paulo State]. Bragantia 26(6): 95–102.

Boserup, Ester. (1965). The conditions of agricultural growth. New York: Aldine.

Brandão, Luiz Fernando, ed. (2012). Relatório de sustentabilidade 2011 [Report of Sustainability 2011]. São Paulo: FIBRIA.

Chazdon, R. (2012). Tropical Forest Regeneration. Bol. Mus. Pará. Emílio Goeldi. Cienc. Nat.7(3): 195–218.

Cunha, G. F., Pinto, C. R. C., Martins, S. R., Castilhos, A. B. (2013). Princípio da Precaução no Brasil após a Rio92: Impacto Ambiental e Saúde Humana [Precautionary Principle in Brazil after Rio 92: Environmental Impacts and Human Health]. Ambiente & Sociedade 16(3): 65–82.

Drummond, José Augusto. (1997). Devastação e preservação ambiental: os parques nacionais do Estado do Rio de Janeiro [Devastation and Environmental preserve: national parks in the Rio de Janeiro State]. Niteroi: EDUFF.

Eskinazi, B. G., Souza, J. G. (2013). Expertise production and territorial Homogenization: eucalyptus monoculture in the Paraíba Valley and production dynamic changes. Mundo do Trabalho 14(2): 194–211.

Evans, T. P., Kelley, H. (2008). Assessing the Transition from Deforestation to Forest Regrowth with an Agent-based Model of Land Cover Change for South-Central Indiana (USA). Geoforum 39: 819–832.

Fairhead, J., Leach, M. (1995). Whose Forest? Modern Conservation and Historical Land Use in Guinea´s Ziama Reserve. RDFN Paper 18c.

Farinaci, Juliana Sampaio. (2012). “As novas matas do Estado de São Paulo”: um estudo multiescalar sob a perspectiva da teoria da Transição Florestal [The new forests of São Paulo State: a multiscalar study on the Forest Transition Theory perspective]. Ph.D. dissertation, Department of Environment & Society, University of Campinas, Campinas.

Farinaci, J. S., Ferreira, L. C., Batistella, M. (2013). Forest Transition and Ecological Modernization: eucalyptus forestry beyond good and bad. Ambiente & Sociedade 16(2): 25–44.

Fenning, Trevor, ed. (2014). Challenges and Opportunities for the World´s Forest in the 21st Century. Edinburgh: Springer.

Ferreira, G. M. V., Oliveira, L., Talamini, E. (2006). Posicionamento Estratégico das Cooperativas Agropecuárias de Leite: O Caso da Cooperativa de Lorena e Piquete no Vale do Paraíba [Strategic Positioning of Agricultural Unions: the case of Lorena and Piquete unions in the Paraíba Valley]. Paper presented at the XLIV Congress of SOBER: Administração Rural e Gestão do Negócio, Fortaleza, July 23.

Foley, J. A., Defries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kuvharik, C. J., Monfreda, C., Patz, J. A., Prentice, I. C., Ramankutty, N., Snyder, P. K. (2005). Global consequences of land use. Science 309(5734): 570–574.

Foster, A. D., Rosenzweig, M. R. (2003). Economic Growth and the Rise of Forests. The Quarterly Journal of Economics 118(2): 601–637.

Fundação SOS Mata Atlântica/INPE. (2011). Atlas dos remanescentes de Mata Atlântica período 2010-2011 [Atlas of the Atlantic Forest Remnants, period of 2010-2011]. São Paulo: Fundação SOS Mata Atlântica/INPE.

Itani, M. R., Barros, C. M., Figueiredo, F. E. L., Andrade, M. R. M., Mansor, M. T. C., Mangabeira, R. L., Carvalho, V. S., eds. (2011). Subsídios ao planejamento ambiental: Unidade de Gerenciamento de Recursos hídricos Paraíba do Sul [Subsidies for Environmental Planning: Hydrographic Unit Water of Resources Management of Paraíba do Sul]. São Paulo: SAM.

Jenzen, Daniel H. (2002). Tropical dry forest: Area de Conservación Guanacaste, northwestern Costa Rica. *In* Handbook of Ecological Regrowth, vol. 2 Regrowth in

Practice. Perrow, M. R. and Davey, J., eds. Pp. 559–583. Cambridge: Cambridge Univ. Press.

Lambin, E. F., Geist, H. J., Lepers, E. (2003). Dynamics of Land-use and Land-cover Change in Tropical Regions. Annu. Rev. Environ. Resour. 28: 205–241.

Lambin, E. F., Meyfroidt, P. (2010). Land use transitions: Socio-ecological feedback versus socio-economic change. Land Use Policy 27(2): 108–118.

Lepsch, I. F., Bellinazzi Jr, R., Bertolini, D., Espíndola, C. R. (1991). Manual for Utility Survey of the Physical Environment and Land Classification by the System of Land Use Capacity, 4th ed. Campinas: Brazilian Society of Soil Science.

Li, Nuyun. (2014). Sustainable Forest Management in China: Achievements in the Past and Challenges Ahead. *In* Challenges and Opportunities for the World´s Forest in the 21st Century. Fenning, Trevor, ed. Pp. 93–122. Edinburgh: Springer.

Lima, A. R., Capobianco J. P. R., eds. (1997). Mata Atlântica: avanços legais e institucionais para sua conservação [Atlantic Forest: institutional and legal advances to its conservancy]. São Paulo: ISA.

Liu, J., Hull, V., Batistella, M., Defries, R., Dietz, T., Fu, F., Hertel, T. W., Izaurralde, R. C., Lambin, E. F., LI, S., Martinelli, L. A., Mcconnell, W. J., Moran, E. F., Naylor, R., Ouyang, Z., Polenske, K. R., Reenberg, A., Rocha, G. M., Simmons, C. S., Verburg, P. H., Vitousek, P. M., Zhang, F., Zhu, C. (2013). Framing Sustainability in a Telecoupled World. Ecology and Society 18(2): 26.

Mahmood, R., Pielke, R. A., Hubbard, K. G., Niyogi, D., Bonan, G., Lawrence, P., Mcnider, R, Mcalpine, C., Etter, A., Gameda, S., Qian, B., Carleton, A., Beltran-Przekurat, A., Chase, T., Quintanar, A. I., Adegoke, J. O., Vezhapparambu, S., Conner, G., Asefi, S., Sertel, E., Legates, D. R., Wu, Y., Hale, R., Frauenfeld, O. W., Watts, A., Shepherd, M., Mitra, C., Anantharaj, V. G., Fall, S., Lund, R., Treviño, A., Blanken, P., Du, J., Chang, H., Leeper, R., Nair, U. S., Dobler, S., Deo, R., Syktus, J.

(2010). Impacts of Land Use/Land Cover Change on Climate and Future Research Priorities. American Meteorological Society 91(1): 37–46.

Mather, A. S., Needel. C. L. (1998). The forest transition: A theoretical basis. Area 30(2): 117–124.

Mello, T. F. (2009). Estrutura da vegetação, cobertura florestal e preferências de uso da paisagem associadas a vertentes: as quase-florestas de São Luiz do Paraitinga (SP) [Vegetation structure, forest cover, and land use preferences in the landscape associated with aspects of topography: the almost forests of São Luiz do Paraitinga (SP)]. M.A. thesis, Department of ecology, University of São Paulo, São Paulo.

Meyfroidt, P., Lambin, E. F. (2009). Forest transition in Vietnam and displacement of deforestation abroad. PNAS 106(38): 16139–16144.

Montebello, A. E. S., BACHA, C. J. C. (2009). Avaliação das pesquisas e inovações tecnológicas ocorridas na silvicultura e na produção industrial de celulose no Brasil [Evaluation of the researches and technological innovations in forestry and in the industrial production of pulp in Brazil]. RESR 47(2): 485–517.

Mora, C. (2014). Revisiting the Environmental and Socioeconomic Effects of Population Growth: a Fundamental but Fading Issue in Modern Scientific, Public, and Political Circles. Ecology and Society 19(1): 38.

Pauleit, S., Ennos, R., Golding, Y. (2005). Modeling the environmental impacts of urban land use and land cover change—a study in Merseyside, UK. Landscape and Urban Planning 71: 295–310.

PAM/IBGE (Instituto Brasileiro de Geografia e Estatística). (1997). Produção Agrícola Municipal, 1995 [Agricultural Production per Municipality, 1995]. Rio de Janeiro: IBGE.

PAM/IBGE (Instituto Brasileiro de Geografia e Estatística). (2012). Produção Agrícola Municipal, 2011 [Agricultural Production per Municipality, 2012]. Rio de Janeiro: IBGE.

PPM/IBGE (Instituto Brasileiro de Geografia e Estatística). (1978). Pesquisa Pecuária Municipal, 1975 [Livestock Survey per Municipality, 1975]. Rio de Janeiro: IBGE.

PPM/IBGE (Instituto Brasileiro de Geografia e Estatística). (1995). Pesquisa Pecuária Municipal, 1995 [Livestock Survey per Municipality, 1995]. Rio de Janeiro: IBGE.

PPM/IBGE (Instituto Brasileiro de Geografia e Estatística). (2012). Pesquisa Pecuária Municipal, 2012 [Livestock Survey per Municipality, 2012]. Rio de Janeiro: IBGE.

Perz, S. G. (2007). Grand Theory and Context-Specificity in the Study of Forest Dynamics: Forest Transition Theory and Other Directions. The Professional Geographer 59(1): 105–114.

Ramos, R. S. (2011). O Sistema de Proteção Ambiental e a Polícia Militar [The Environmental Protection System and the Military Police]. *In* Direto Militar: Doutrina e Aplicações [Military Law: Military Doctrine and applications]. Ramos, D. T., Roth, R. J., Costa, I. G., eds. Pp. 398–406. Rio de Janeiro: Elsevier.

Rosenberg, N. J., Black, B. L. Verma, S. B. (1983). Microclimate: the biological environment, 2nd ed. Chichester: John Wiley & Sons.

Rudel, T. K. (2002). Paths of destruction and regeneration: globalization and forests in the tropics. Rural Sociology 67(4): 622–636.

Rudel, T. K., Coomesb, O. T., Moran, E., Achardd, F., Angelsene, A., Xuf, J., Lambin, E. (2005). Forest transitions: towards a global understanding of land use change. Global Environmental Change 15: 23–31.

Sachs, R. C. C., Pinatti, E., Giannotti, J. D. G., Francisco, V. L. S., Bezerra, L. M. C. (2006). Caracterização da Pecuária no Vale do Paraíba Utilizando a Análise Multivariada [Characterization of Livestock in the Paraíba Valley Using Multivariate Analysis]. Pesquisa e Tecnologia 3(2).

Spellerberg, I. F. (1996). Plantation forests protect biodiversity?—Too much of a generalization to be true. New Zealand Forestry 39: 19–22.

Tilman, D., Balzer, C., Hill, J., Befort, B. L. (2011). Global food demand and the sustainable intensification of agriculture. PNAS 108(50): 20260–20264.

Vanwey, L. K., Ostrom, E., Meretsky, V. (2005). Theories Underlying the Study of Human-Environment Interactions. *In* Seeing the Forest and the Trees: Human-Environment Interactions in Forest Ecosystems. Moran, E. F., Ostrom, E., eds. Pp. 23–56. Cambridge: MIT Press.

Vieira, E. T., Santos, M. J. (2012). Industrialização e desenvolvimento regional: política do CODIVAP no Vale do Paraíba na década de 1970 [Industrialization and regional development: CODIVAP policy in the Paraíba Valley in the 1970s]. Desenvolvimento Regional em Debate 2(2): 161–181.

Wright, S. J. (2010). The future of tropical forests. Annals of the New York Academy of Sciences 1195: 1–27.

Wu, Y., Liu, S., Sohl, T. L., Young, C. J. (2013). Projecting the land cover change and its environmental impacts in the Cedar River Basin in the Midwestern United States. Environmental Research Letters 8(024025).

Zuquim, M. L. (2007). Os caminhos do rural: uma questão agrária e ambiental [The rural paths: an agrarian and environmental question]. São Paulo: SENAC.

Capítulo IV

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Socioeconomic Collapse of Rural Areas: Challenges for Agriculture and Opportunities to the Atlantic Forest Transition

Abstract: Centuries of pressure over the Atlantic Forest has led the biome to a critical level of remaining forest. Natural regeneration has been the major process explaining forest cover increase since the 1960s. The forest regeneration is related to agricultural constraints such as land use policies, environmental legislation, agricultural modernization, economic development and biophysical aspects of the landscape. This set of Forest Transition pathways is analyzed for the Paraíba Valley region, São Paulo State/Brazil. During the 18th and 19th centuries, the Valley's farms were responsible for providing the largest portion of the state's wealth. Nowadays, the Valley contributes only about 6% to the state's GDP and the contribution of rural activities is insignificant. Between 1962 and 2011, forest cover area increased from 225 to 446 thousand hectares. Based on map analyses, field observation, rural household surveys and secondary data we conclude that the diminished land use pressure in the Paraíba Valley is permitting deforested areas' return to forest cover. Collective action and agricultural modernization pathways influenced and still are influencing this Forest Transition. The major trend identified on 435,345 ha (pasturelands) or 30% of the Valley is the re-establishment of forest vegetation cover.

Key words: Institutional Analysis and Development framework; Atlantic forest resilience; rural household survey; collective action; agricultural modernization.

1. Introduction

The Anthropocene, a new geological epoch (Steffen *et al.* 2011), is a comprehensive example of how much human society has changed the Earth's surface and its life support systems. Among the significant drivers of global environmental changes, is land use conversion (Washington-Ottombre *et al.* 2010). This dynamic process is highly associated with carbon dioxide emissions, water scarcity, climatic changes and social impacts such as human displacement (Foley *et al.* 2005). To feed a population of 7 billion-- projected to reach 9 billion in the next few decades-- poses a complex challenge. In the past century, the “Green Revolution” dealt with this challenge through land use intensification, mechanization, intensive use of pesticides and fertilizers, and varietal and genetic improvements (Matson *et al.* 1998; Kush 2001). In Brazil, the “Green Revolution” came in the 1960s and led the country to an “Agricultural Modernization” period (Buainain *et al.* 2014). The new agro-production system of Brazil made it one of the world’s largest producers of agribusiness commodities in this century.

Scientific research about land use transitions are dealing with geographical information systems and socioeconomic analysis to interpret how human decisions, institutions and biophysical aspects of the environment interact and results in land use and land cover changes (Lambin and Meyfroidt 2010). Human decisions hold a key importance in how we allocate land according to specific purposes, not always guided by rational choices to maximize profits or to follow policies but also motivated by subjective and moral values (Moran and Ostrom 2005; Koontz 2010). Therefore, the human decisions taken at the level of rural properties is valuable information to understand land use decisions, better support public policy and predict future scenarios (Irwin and Geoghegan 2001; Areal and Riesgo 2014; Beilin *et al.* 2014). In this context the use of the rural household survey is a widespread research method (Silvano *et al.* 2005; Hu *et al.* 2014; Ango *et al.* 2014; Urpelainen and Yoon 2015).

Forest transition theory (FT) predicts that after a period of deforestation the descendant trajectory of forest tends to stabilize and then begins a period where the gains in forest area are greater than losses to deforestation (Rudel *et al.* 2005). To explain this transition process many researches worldwide developed national and global studies addressed to comprehend its pathways (Chazdon 2012; Lambin and Meyfroidt 2010; Gray and Bilsborrow 2014; He *et al.* 2014). Thus, understanding forest transition pathways is an important topic of the socio-environmental sciences since it is through its understanding that key information to boost environmental improvement and forest conservancy are revealed.

2. Context

In recent decades Brazil has been facing deforestation and forest degradation in the Amazon, mostly by logging and opening of land for agriculture (Godar *et al.* 2014), while in the Atlantic Forest increases in forest cover has become a significant trend in the biome (Baptista 2008; Lira *et al.* 2012; Farinaci 2012; Farinaci and Batistella 2012). Deforestation rates at the national level may conceal significant variations in the rates and patterns of forest changes in particular regions (Tucker and Southworth 2005). As is documented in history and forest science, the Atlantic Forest reached very low levels of conservation through centuries of colonization and conversion of forest into agropastoral uses (Tabarelli *et al.* 2005; Victor *et al.* 2005; Lira *et al.* 2012). During the Brazilian era of initial industrialization (1950-1980) the country experienced huge fluxes of migration and rapidly became urban. In the Atlantic Forest biome lie the most developed regions of Brazil, concentrating 59% of the Brazilian population (IBGE 2010), and important economic agro-industrial centers such as São Paulo and Rio de Janeiro metropolitan areas. The biome encompasses 17 States (13% of the Brazilian territory) and is a very social, cultural and economic heterogeneous region.

Forest cover data from Fundação SOS Mata Atlântica/INPE (2014) for the last three decades shows a trend of decrease in deforestation with different rates in each state, suggesting that the biome did not experience change uniformly. The policies addressed at the national or state levels failed to specific local conditions (Campbell *et al.* 2006). The eastern portion of São Paulo State (region of the Paraíba Valley) showed a significant rate of forest cover increase from 225 to 446 thousand hectares (+98%) (Borgonovi *et al.* 1967; Capítulo I) between 1962 and 2011, contrasting with the general trend of the biome in São Paulo State and Brazil (Farinaci and Batistella 2012; SOS Mata Atlântica/INPE 2014). The reasons why are complex. The Valley is characterized by a relief dominated by hills, two mountain ranges, and flat areas covered by urban infrastructure. During the 18th and 19th centuries, the farms on the Valley were responsible for providing the largest portion of the state’s wealth (Zuquim

2007; Eskinazi and Souza 2013). Despite that, nowadays, the Valley contributes with only about 6% of the state's GDP, and the contribution of rural activities is insignificant (Itani *et al.* 2011).

The Paraíba Valley of São Paulo State is a part of the Paraíba watershed that spreads between the States of São Paulo, Minas Gerais and Rio de Janeiro and provides the bulk of the water supply to a population around 10 million inhabitants (Itani *et al.* 2011) mainly for Minas Gerais and Rio de Janeiro. In November of 2014, after the worst water crisis in São Paulo in the last 80 years, the Federal Court of Justice accepted a request from São Paulo's governor to allow the state to use this watershed to improve the water supply system of São Paulo metropolitan region (Editorial: Folha de São Paulo 2014). This chapter in the Paraíba Valley history raises concern about the future of the watershed management and for the maintenance of its ecosystems services.

Less than 30% of Paraíba Valley is under the protection of conservation units of full protection, thus, imposing a key role to private rural properties in the conservation of the Atlantic Forest biome and its ecosystems services. The paper's focus addresses the following questions: *(a)* how decisions at the rural property level can contribute to the increase of forest cover in the Paraíba Valley, São Paulo State? *(b)* How are these decisions related to political, social, economical and environmental variables? *(c)* How these variables through land use changes will affect environmental outcomes? Ultimately, this research is intended to enable a future perspective to the study region based on the analysis results, and better support policy decisions associated with forest transitions.

3. Methods

3.1 Sampling

The Paraíba Valley within São Paulo State comprises 34 municipalities and is classified by the State as *Hydrographic Unit Water of Resources Management of Paraíba do Sul* (Itani *et al.* 2011). To decide the municipalities to be sampled, a set of variables (Table 4.1) were chosen based on the available knowledge about the region's land use and land cover dynamics (Funcate 2012; Capítulo I) and the research team’s expertise. Given a complex and heterogeneous region in terms of economy and social aspects (Itani *et al.* 2011), and the multiple contexts of FT (Rudel *et al*. 2005; Perz, 2007; Lambin and Meyfroidt 2010; Grau and Aide 2008), the selected variables represent significant drivers to the FT context in the Paraíba Valley (Farinaci *et al.* 2013; Capítulo II; Capítulo III).

Among the selected variables a parametric outlier approach known as the *modified Thompson tau technique* was conducted. An outlier is a data point which is significantly different from the remaining data, also referred to as anomalies. Therefore, an outlier contains information about abnormal characteristics of the systems and entities, which impact the data generation process (Aggarwal 2013). Thus, taking into account the potential impact of the outlier to the survey results, the outlier was discharged to not create bias in the field data, then, the municipality with best performance (maximum value) of each variable was chosen.

Table 4.1. Variable dataset to select the municipalities within the Paraíba Valley.

	Brief description of variables	Mean	Std. deviation
Forest[ϕ]	Mean variation of forest cover percentage within the municipality between 1985 and 2011	22.69287	11.21238
Eucalyptus[ϕ]	Percentage of increase in eucalyptus plantation between 1985 and 2011	3.17766	3.832879
Municipal revenue [ɵ]	Mean value of the revenue ($) per municipality between 1985 and 2011	89891625.22	198996234.1

[ϕ] Data from Capítulo I.

[ɵ] Data from the State Foundation of Data Analysis System (*SEADE* <https://www.seade.gov.br/> In: “população e estatísticas vitais”).

The modified Thompson value for 34 data points (municipalities) based on significance level of 0.05 is $\tau = 1.9174$.

3.2 Rural Household Survey

The survey was structured to cover any kind of rural property (by size and activity), addressing questions to understand what is happening in the countryside of the Paraíba Valley’s rural activities (e.g., economic, leisure, social, and the region's perspective about the future of the rural properties) and how these contexts interact with forest cover dynamics and agricultural land uses. As the first step of the survey application, the interviewer presented a summary about the research purposes to make sure that the interviewee has been noted land changes within the rural property or in landscape level, with consequences to forest cover dynamics. After this methodological step the survey was conducted per municipality until fill the sample size of 30 questionnaires. After finishing a specific municipality the survey followed to the next until a total of 90 questionnaires was reached in 3 municipalities.

To select the rural properties within the municipality, the research team used information from local public agencies such as rural extension and rural unions, land use and land cover maps to detach forest cover areas, and road maps. Based on these data field work campaigns were conducted between September and November of 2014. The questionnaire was structured in 7 broad questions with multiple choices and with the option “other” to the case when the interviewee had not choice or gave a different answer out of multiple choices. The overarching question behind all of them or the “umbrella” question was – what is happening in the countryside to explain increases in forest cover area?

3.3 Data and analysis

To deal with the questionnaire results and improve the understanding about land use and socioeconomic dynamics in the Paraíba Valley countryside, two topographic parameters were overlaid with forest cover: topographic wetness index (TWI) and slope. The topographic parameters derived from the Advanced Spaceborne Thermal Emission and Reflection Radiometer Global Digital Elevation Model, grid size of 30x30 meters (ASTER GDEM). The TWI characterizes the surface-water saturation zones and the water content in the soils (Minella and Merten 2012), calculated by: $\mathrm{Ln}(\alpha/\tan\beta)$; where α represents (specific catchment area) upslope area per unit contour length, and $\tan\beta$ is local down slope (Silva *et al.* 2013). Giving the hydric concerns in region and its importance in water supply, the TWI was chosen as a topographic parameter to measure how the forest cover dynamics are behaving over more likely water-saturated areas. These areas comprehend core hydrologic process in the watershed as runoff formation and soil saturation after rain, as well as represent the upstream contributing areas and streams’ network (Beven and Kirkby 1979), it is also a variable to characterize biological process such as vegetation patterns, and forest site quality (Sorensen *et al.* 2005). Therefore, TWI indentifies the hydrologic patterns of the watershed, key information to agricultural and environmental watershed management, mainly for water conservation (Minella and Merten 2012; Silva *et al.* 2013). The slope parameter is an indicator of land use constraints to irrigation, cattle and mechanization, thus, impacting agricultural activities and land use decisions.

Thus, based on the overlaid results from topographic and forest cover information, analysis with the interviewees' answers were conducted to evaluate how the land dynamics matches with land use decisions and social aspects of the countryside. Also, socioeconomic data to characterize each municipality was used to support the analysis. Therefore, from the results and interviewees' stated future perspectives, tendencies for forest regeneration and rural land occupation were discussed.

3.4 Institutional analysis

To comprehend the institutional[13] dimension that underlies forest transition in the study region, the Institutional Analysis and Development – IAD framework (Ostrom *et al.* 1994) was applied. The IAD framework is a multi-tier conceptual map aimed to identify the elements and general relationships among these elements that one needs to consider for institutional analysis (Ostrom 2011). The framework has a conceptual unit, the *Action arena* composed of an *Action situation* component and an *Actor* component. Also, the *Action arena* is interrelated to the exogenous variables of rules, physical conditions, and community; the outcomes and evaluative criteria (Ostrom *et al.* 1994; Ostrom 2005). The IAD framework views institutions as human-made system within which individual choices take place and which configure consequences of the respective choices (McGinnis 2011). It assumes a context to the particular interaction in which the general network of regular actors would be analyzed, the particular rules-in-use, and the particular common outcome that they hope to achieve (Ostrom 2005).

4. Results and Discussion

4.1 Socioeconomic characterization

The outlier analysis identified three municipalities to be sampled (Table 4.2). Each municipality demonstrated different levels of economic development (Figure 4.1.a), population dynamics, and geographical situation (Figure 4.2); however, they

[13] To this paper we assume the concept of Institution from *Understanding Institutional Diversity* (Ostrom 2005).

converged on several common points such as terrain dominated by hills, low availability of labor for agricultural jobs, and positive rates of forest cover increase. In the Paraíba Valley agricultural land use abandonment has been the major land trajectory leading to the forest transition (Capítulo III). Agricultural land use abandonment is driven by a combination of different factors, ranging from physical constraints of the landscape to more socioeconomic drivers (Strijker 2005; Kizos and Koulouri 2006; Beilin *et al.* 2014).

Table 4.2. Selected municipalities to develop the rural household survey.

	Outlier	Threshold*	Best performance (maximum value)	Municipality
Forest	29.5	21.4	21.2	Bananal
Eucalyptus	14.5	7.3	6.6	Paraibuna
Municipal revenue	995218101.3	381555379.2	335204038.3	Taubaté

* The threshold value is derived from the equation (τ*standard deviation).
The “Best performance” value corresponds to the elected “Municipality” to the survey.

Based on the main land use activities within the rural property according the interviewees' answers, Table 4.3 was formulated.

Table 4.3. Description of the rural activities within the rural property.

Rural activities within the property	Bananal	Paraibuna	Taubaté
Dairy	9	6	12
Dairy and buffalo	1	--	--
Dairy and pig	1	--	--
Dairy and leisure	1	--	--
Dairy and horticulture	--	1	3
Dairy and beef	--	2	3
Dairy and eucalyptus	--	2	--
Dairy, beef and eucalyptus	--	1	--
Dairy, beef, eucalyptus and rural tourism	--	1	--
Dairy, rural tourism, leisure and sausage	--	1	--
Dairy and cachaça	--	1	--
Dairy and rural tourism	--	1	--
Beef	2	1	--
Beef and leisure	2	1	--
Beef, leisure and cachaça*	1	--	--
Beef and cachaça	1	--	--
Leisure	4	2	9
Rural tourism	2	2	1
Rural tourism and leisure	2		--
Eucalyptus plantation	--	2	1
Horticulture	--	3	1
Fruits	--	2	--
Agroforestry	--	1	--
Abandoned$^{\phi}$	4	--	--

* Traditional Brazilian alcohol from sugar cane.

$^{\phi}$ No use according the interviewees – the landowners has no immediate plans to use the rural property to economics or social purposes.

Cattle for beef and dairy production is the main rural activity but varying in quantity (Figure 4.1.b, 4.1.c) and management techniques among the municipalities. From the survey, forty six rural properties have dairy production; 78% of them use management techniques such as semi-confinement, rotation and/or best adapted and more productive breeds of dairy cattle. 94% of the dairy producers in Taubaté use at least one of these techniques, while in Paraibuna 96%, and Bananal 25% do. The more productive dairy cattle breeds are not able to graze in mountainous areas and this constrains the farmers to adopt semi-confinement and the intensification use of flat areas, to the Paraíba Valley case, predominantly along the stream network.

The low contribution of Paraíba Valley to the State's agricultural revenue, about 1.9% (SEADE[14]), reveals the stagnant rural economic situation of the region. The farm size in the sample ranges from 5 to 1000 ha with average size of 125 ha, thus, with a predominance of small and medium rural properties. In Brazil, the rural properties smaller than 500 ha contributed with approximately half of the Brazilian agricultural production in 2006; however, 9.5% of rural properties contributed with 86% to the national agricultural revenue in the same year (Helfand *et al.* 2014). The very concentrated profits to a small group reveals the effect of rural economic policies that favor agribusiness driven by the principles of large scale, high productivity and high intensified agriculture, adopted by governmental policies since the 1960s (Stotz 2012; Silveira 2014; Garcia 2014). The effects of these policies is the marginalization of the less suitable agricultural areas, mainly the ones with severe constraints to mechanization, mountain zones and natural handicaps (Cramer *et al.* 2008; Beilin *et al.* 2014; Garcia 2014). The contribution of each municipality surveyed, highlight the economic scenario of the marginalized agricultural areas (Figure 4.1.d).

[14] SEADE – State System of Data analysis (Data serie: *Informação dos Municípios Paulistas* < http://produtos.seade.gov.br/produtos/imp/>).

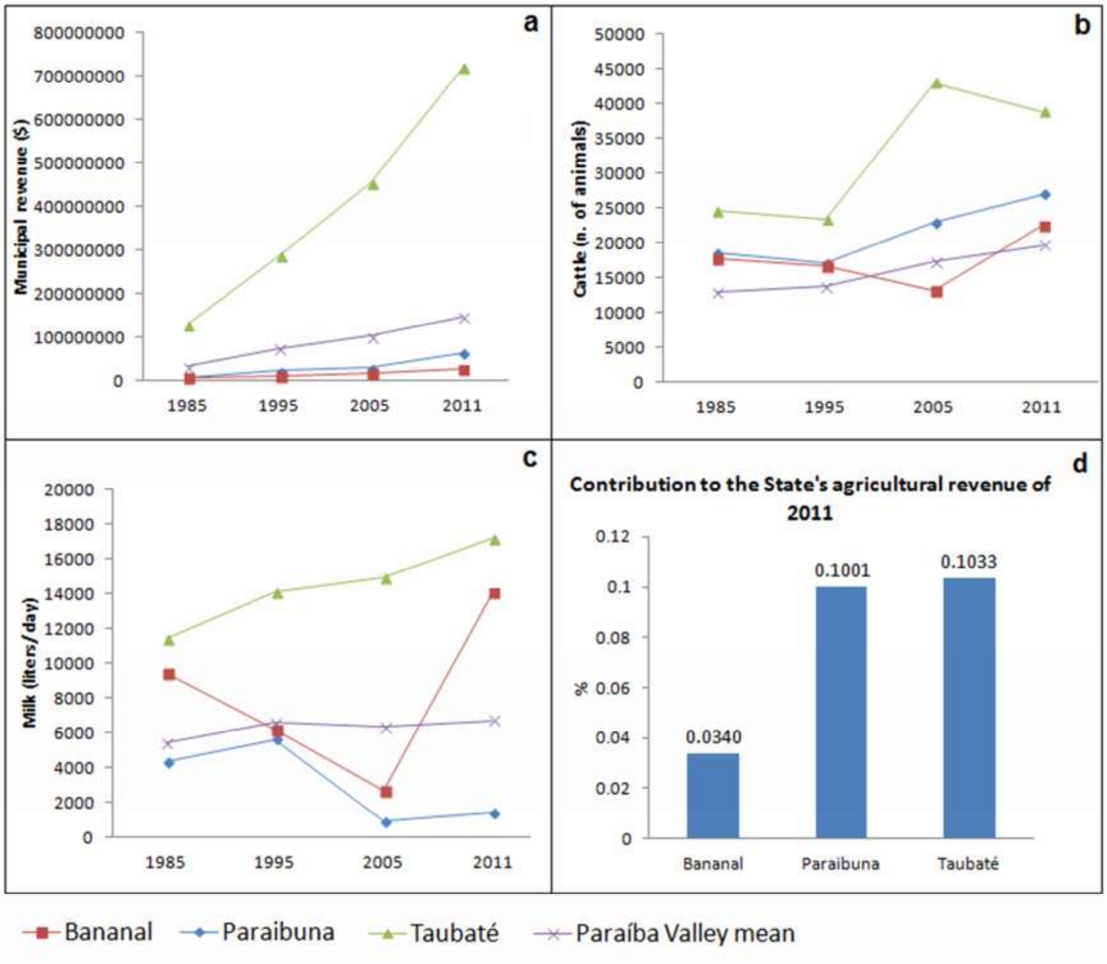

Figure 4.1. Socioeconomic data of the surveyed municipalities and the mean of Paraíba Valley.

The aging of the rural population is a concern in countries of Europe, United States and more recently also in Brazil, because there is a growing aging of the population and outmigration of the young in rural areas. The average age of the sampled population is 59 years old ranging from 23 to 82. For regions more economically dynamic, as the whole of São Paulo State, farmers 35 years old are less likely than in less developed regions such as the North and Northeast (Vieira Filho 2014). 4.5% of the sample represents landowner's younger than 35 years. Between 1950 and 2010, the Paraíba Valley urban population growth was about +841%, Bananal +270%, Paraibuna +212%, and Taubaté +674%. In 2010 the Taubaté population represented 14% of the region while Bananal 0.5% and Paraibuna 0.8%. Paraibuna is the only municipality demonstrating positive rates of rural population growth, +42% from 1980 to 2010 contrasting with Taubaté -23%, and Bananal -59%. The Paraíba Valley rural population in 2010 was 6%, decreasing from 56% in 1950

(IBGE 2010). In 2011 Bananal presented the highest rate of forest cover, 51% or 31112 ha of its territory, while it was the municipality with lowest rural population, 2065 inhabitants (25% of its population) in 2010.

Based on field work information, these population dynamics are very close to the region's economic development. Taubaté with high scores of industrialization and economic growth, attracted migration to its urban area, as well as São José dos Campos, the major economic municipality of the region. Even Bananal, the farther and geographically most isolated municipality (Figure 4.2) of the region suffered migration flows to Taubaté and São José dos Campos during the second half of the twenty century impacting its population dynamic, noted by Viera and Santos (2012).

73% of the rural properties have no exclusive income from rural activities. Among dairy farms, about 58% has exclusively rural income. In Brazil there is a wide variety of public policies to keep the families on agriculture even if they have no exclusive rural income, like the rural retirement and "*Bolsa Família*" (Helfand *et al.* 2014). The rural retirement is a right for rural workers older than 55 years old for women and 60 for men. In the Paraíba Valley, 47% of farmers interviewed were older than 60 years, and according to the ones that have the rural retirement (twenty three), the economic assurance provided by this policy is vital to keep themselves in the rural property.

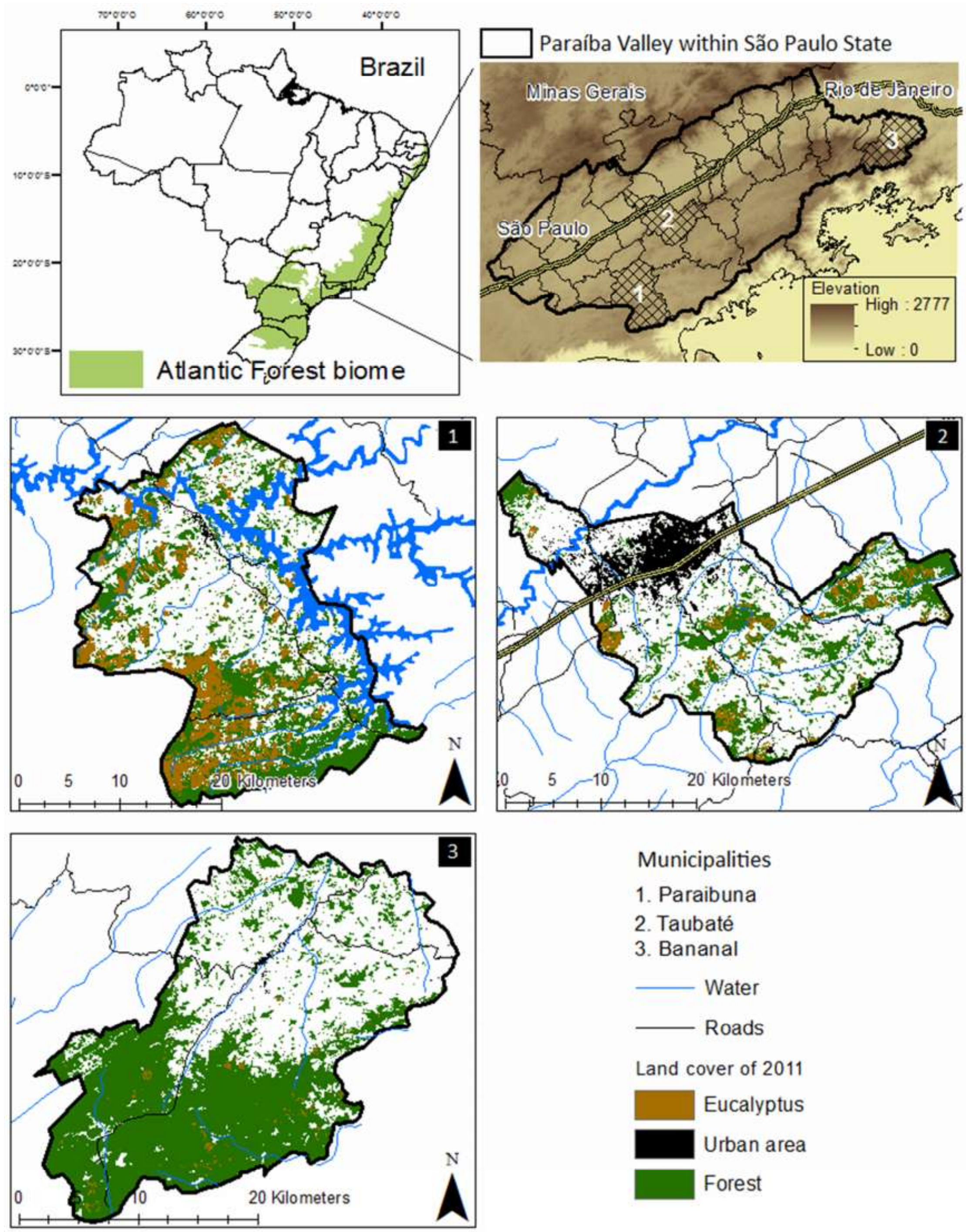

Figure 4.2. Paraíba Valley study region. The municipalities surveyed.

4.2 Land use decision and forest transition pathways

Forest cover changes over time. As can be seen in Figure 4.3, there has been a predominant dynamic in recent decades: net forest gain. Based on previous research (Capítulo I), deforestation tends to diminish and concentrate over the first stages of successional forest, up to 10 years of growth, thus reducing pressure over old forest remnants settled before 1985, and for the new patches established until 1995.

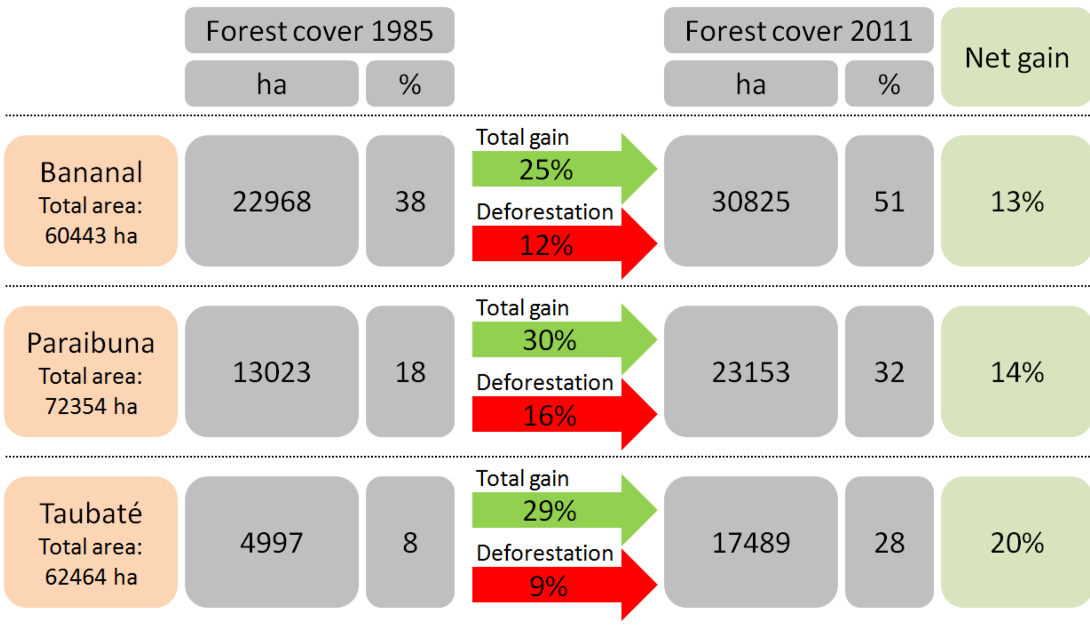

Figure 4.3. Temporal dynamics of forest cover to the municipalities of Bananal, Paraibuna and Taubaté.

Since 1985 the net forest gain was more than 10% of municipalities' territories--reaching 20% in Taubaté. The general results of net gain reveals a process of forest transition replacing former pasturelands, eucalyptus and agricultural areas (Capítulo I), previously established over deforested areas during the last two centuries of colonization (Dean 1996; Victor *et al.* 2005). Thus, the transition to forest means a return to the native landscape found in Brazilian Atlantic region before the European colonization in areas less favorable to mechanized modern agriculture.

4.2.1 Topography and water

Among the slope classes defined by Lepsch *et al.* (1991) in the “Manual for Utilitarian Survey of the Physical Environment and Land Classification by the System of Land Use Capacity” – 0-3% (1), 3-6% (2), 6-12% (3), 12-20% (4), 20-40% (5), >40% (6) – the majority of new forest areas occurred in the classes 5 and 6 (Figure 4.4). These classes mean terrain less suitable for agriculture, livestock, and suitable for restricted forestry operations and conservancy.

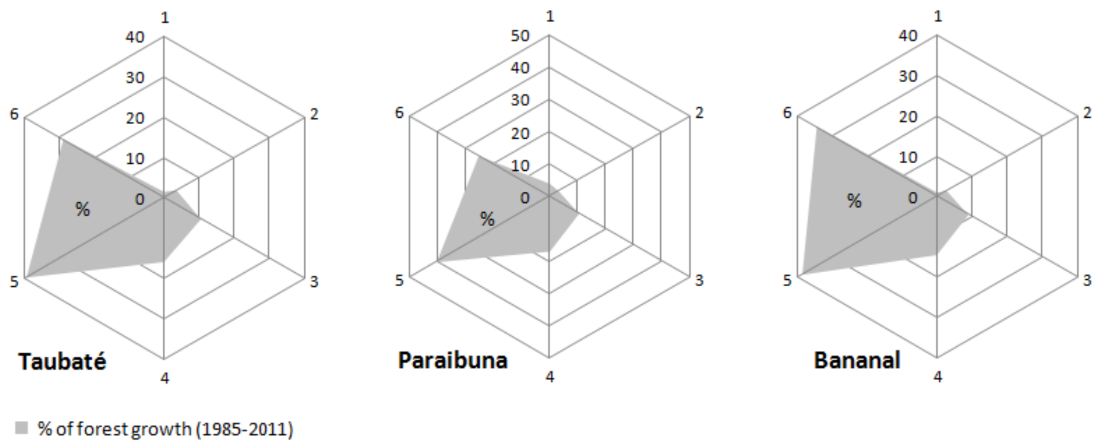

Figure 4.4. The pattern of forest cover increase over the municipalities' topography.

According to the answers from rural properties with at least one agro-pastoral activity (68 in total), 78% recognized the most steep slopes as a very significant constraint to land use, thus more likely to be abandoned and replaced by forest through natural regeneration, sustaining the results in Figure 4.4. These hills as noted by Silvano *et al.* (2005) have low opportunity costs as these areas are typically unsuitable for pasture and agriculture, however harbor spring water sources. According to the authors, due the awareness about forest's role in maintaining private water supplies, farmers are more prone to let forest grow around the useful springs than around the river margins.

Over the sensible hydrologic zones defined by the TWI, 19% of forest total gain (between 1985 and 2011) occurred in Taubaté over these areas, 21% in Paraibuna, and 29% in Bananal. Therefore, it is likely that forest growth dynamic was not an oriented process to occupy the most sensible hydrologic zones in the watershed, thus suggesting that there was not a strategic plan to forest restoration in the last decades focused on water security. These results reveals natural forest regeneration in the Paraíba Valley is more likely to occur in steep slopes than sensible hydrologic zones.

Between 2013 and 2014 São Paulo State faced the worst water crisis in recent decades (Editorial: Folha de São Paulo 2014). During 2014 many properties faced water scarcity that compromised their rural activities. This scenario was influential in the interviewees' answers and to catalyze farmers' attitude to adopt water conservation strategies. In relation to the sensible hydrologic zones defined by TWI it is likely that future land use mapping will reveal new tendencies of forest growth over these areas, more water-oriented. Thus, the observations made by Silvano *et al.*

(2005) reveals a potential pathway of forest grow by land use decisions influenced by water concerns, and reinforced by the farmers' water crisis faced during 2014. A decline in the provision of ecosystem services clearly contributed to initiate the forest transition as a socio-ecological feedback (Lambin and Meyfroidt 2010).

This future scenario could be highly improved by the enforcement of the new Forest Code (Law n^0 12651 of 2012) through the *Rural Environmental Cadastral Survey*[15] that forces the protection of river margins in 15 meters at least, and springs, known as *Permanent Preservation Areas*. The protection strategy encompasses the closure of these areas by fence, and prohibits the use for agriculture and livestock. Based on field information, this strategy allows natural forest regeneration, the mainstream of forest cover increase in the Atlantic Forest biome (Farinaci 2012).

4.2.2 Economic development and agricultural modernization pathways

Since the Paraíba Valley has changed in social and economic aspects during recent decades, landscape patterns have changed also. The Paraíba Valley historical landscape is a mosaic of land uses and forest patches embraced by two mountain ranges within a “sea o hills”. Therefore, socioeconomic dynamics were and still are influencing landscape changes, mainly the spatiotemporal forest cover dynamics (Capítulo III).

The survey focused some questions to deal with socioeconomic aspects potentially related to the forest cover increase. When the interviewees were asked about potential variables to explain “why the forest areas are increasing?” fifty four associated this phenomenon with socioeconomic changes in the region. Among the choices related to socioeconomic aspects, the low availability of labor for agricultural activities, and the migration to urban areas motivated by expectations of better living conditions were predominant.

The low availability of labor for agricultural activities is a generalized problem in the study region, as noted by farmers, unions and rural-public agencies. This phenomenon is not exclusive to Paraíba Valley, as observed in other regions of Brazil (Buainain *et al.* 2014) motivated by a gamut of factors that influence, finally, the

[15] The Rural Environmental Cadastre is a key tool to assist the process of environmental regularization of rural properties. It encompasses a georeferenced survey of the property, including the delineation of the Permanent Preservation Areas, Legal Reserve, remnants of native vegetation, consolidated rural areas, areas of social interest and public service, in order to draw a digital map from which the extension of the areas are calculated for environmental diagnosis (http://www.mma.gov.br/desenvolvimento-rural/cadastro-ambiental-rural).

migration from rural to urban areas. Between these factors there are at least three of them playing a major influence in the Paraíba Valley context; mechanization, job opportunities outside rural areas and better living conditions in urban centers. The topography of the Paraíba Valley characterized as a “sea of hills” (Ab'Saber 2003) is a constraint to mechanized agriculture. So, with the exception of eucalyptus plantations, there is no other monoculture system in the Valley. The eucalyptus increased in the last three decades and according to the informants, is stagnated and there is no expectation of new eucalyptus plantation areas in private lands. This result finds echo in the annual report of the major pulp industries that work in the region. During 2012 and 2013, its pulp production used 1.43% of eucalyptus from rural properties; the other 98.57% came from its own lands (Fibria 2014). According to the company, the eucalyptus production in the Paraíba Valley is the most expensive compared with other regions in Brazil where the company acts, due to the topography dominated by steep slopes that make it difficult to conduct forestry operations. Thus, the eucalyptus expansion is taking place in new producer regions of Brazil that offer suitable environmental conditions, as topography adequate to mechanize large scale areas, best land price opportunities, and due to the fact that the company has self-sufficiency of eucalyptus plantations to supply the pulp industry of Paraíba Valley with its own planted areas, discouraging the expansion of eucalyptus inside Valley's rural properties.

Thus, the constraint to mechanization, not exclusively, leads the Valley to a marginalized situation in the modern Brazilian agro-production system. The dependency on fertilizers and pesticides, a strong component of the Brazilian agricultural modernization, increased the costs of production (Stotz 2012). Finally, the non competitive costs and scale to produce coffee, beans, corn, tomato, milk and others compared with the new agricultural frontiers opened during the 1960s and 1980s (Salles-Filho and Bin 2014) influenced the agricultural production in the region. At that time, huge amounts of families that still were in rural villages migrated to urban centers because the lack of job opportunities in rural properties that vanished agricultural production to more-exclusive cattle activities.

At the same time, the industrialization of the Paraíba Valley demanded a new demographic configuration to reach the Brazilian project of the military regime – transform the country from an agro-producer-based economy to an industrial-based economy (Buainain *et al.* 2014). Therefore, São José dos Campos and its neighbor cities as Taubaté attracted workers from many regions of the Valley. According to informants from Bananal, entire rural neighborhoods migrated to São José dos Campos in the 1970s to work. Currently, this flux to São José dos Campos and its neighbors continues, but in the last decade has become more diffuse (IBGE 2010).

The construction of State and Federal roads, oil and gas pipelines across the Valley and other infrastructure projects in the last decade, plus formal and informal job opportunities in urban areas has influenced and still is influencing the establishment of workers in non rural jobs. Thus, there is a challenge to the Paraíba Valley farmers to keep workers in their properties because the costs to keep them are matched by non-rural jobs, a situation which raises the value of the rural wage and increases labor benefits pushing the famers to the limit of their financial condition where the income from land use are not enough to make profits, making the agricultural enterprise unprofitable.

When the farmers lack good economic conditions, the rural activity is not attractive and pushes new waves of rural workers to cities and they find it difficult even to keep the family in the rural area. Due to the urbanization process and the development reached with the increase of the Brazilian medium class, fewer young workers are looking for job opportunities in rural areas in the most developed regions, such as São Paulo State (Vieira Filho 2014).

The phenomenon of socioeconomic changes promoted by the Brazilian industrialization, urban development and agricultural modernization boosted agricultural land use abandonment and forest regeneration in Paraíba Valley. At this point, the economic development FT pathway had influenced the net forest gain in the Paraíba Valley (Capítulo III). However, the agricultural modernization-- as a driver of massive rural exodus, environmental depletion by the intensified use of fertilizers, pesticides and machineries, opening of new agricultural areas over forest and other ecosystems – promoted other side effects such as the marginalization of former agricultural areas, as Paraíba Valley. Therefore, the marginalized agricultural areas lost their rural economic importance leading to a decrease of agricultural activities followed by land abandonment and forest vegetation re-establishment. Reduced land degradation in one place is also to some extent the result of a displacement of food production and wood extraction to other places through trade (Lambin and Meyfroidt 2010). The marginalization of former agricultural areas as a side effect of the Brazilian agricultural modernization was already observed in other regions of Brazil (Borba and Gomes 2006; Balsan 2006; Santana 2008; Neske *et al.* 2013).

4.2.3 Collective action pathway

Considering forests and its related ecosystem services as public goods, volunteer initiatives to boost forest cover inside private properties sheds light on the theory of Collective Action (Olson, 1965). As defined by Ostrom (1998), "social dilemmas" refer to a large number of situations in which individuals make independent choices in an interdependent situation, reforestation initiatives and environmental complaint encompass self-interest and contribute to the production of public goods. Since the promulgation of the Brazilian constitution in 1988, the society is stimulated to execute a new paradigm of public policy management that promotes the decentralization of decisions and enlarges society's participatory role (Carvalho *et al.* 2005). The institutions play key roles in the construction of social arrangements capable of solving environmental problems (Ostrom and Cox 2010).

Given the capability of the IAD framework to comprehend complex socio-ecological systems in order to develop responsible public policies (Ostrom and Cox 2010); two variables related to the forest cover dynamics in the Paraíba Valley were accounted in the framework. Volunteer actions and environmental complaint. The environmental complaint is an interdependent variable of the Environmental System of São Paulo State (Capítulo III).

4.2.3.1 Volunteer reforestation initiatives

Among sixty eight rural properties with at least one agro-livestock activity 51% undertook voluntary reforestation initiative within the property. The rural properties with leisure and tourism activities (thirty four), 61% adopted reforestation initiatives. As expected, tourism and leisure activities in rural areas has more likelihood to promote environmental quality improvements than agro-livestock, since these activities stimulate the recovery and conservation of natural environments (Roque 2013); or as noted by Lambin and Meyfroidt (2010), by the Globalization pathway of FT, as a result of private investments, land privatization and the expansion of global tourism, forest conservation activities increasingly take place on private lands.

Voluntary reforestation initiatives in the Paraíba Valley are related to environmental concerns, mainly water and aesthetical landscape values. 66% of the rural properties that implemented volunteer reforestation initiatives (fifty three) were driven by hydric concerns at least. Among the landowners that adopted volunteer initiatives, 12% had no formal education level, 7% basic, 33% medium high school, and 46% undergraduate level. Thus, as suggested by data and observed by Farinaci (2012), as higher the level of formal education, more likely the adoption of reforestation initiatives.

A remarkable case is the "Águas da Bocaina[16]" project in the municipality of Bananal. In the municipality zone of highlands, an area of 1000 ha was converted to a private conservation area known as Private Reserve of Natural Heritage - PRNH. After the conversion to PRNH the landowners have no rights to explore the land by agro-forestry-livestock activities. The purpose of the PRNH is biological conservation. The project area is contiguous with the Ecological Station of Bananal with an area of 884 ha. The synergy between PRNH and Ecological Station, the biological outcomes reached through the efforts to conserve this area has influenced another landowner in the same region to convert 900 ha of its rural property to PRNH.

4.2.3.2 Ensuring law enforcement

Previous research (Capítulo III) has identified a relationship between environmental policies, law enforcement and individuals' action in the controlling of deforestation. Driven by this find, the survey captured the interviewees' answer about the underlying question of "how deforestation tends to diminish and stay under control in the region?"

A group of seventy five interviewees recognized environmental legislation as a requisite to the control of deforestation. As mechanisms to enforce the environmental legislation, the group highlighted the Environmental Military Police (EMP) surveillance, present in 80% of the answers and the environmental complaint made by local population, present in 60% of answers. The EMP surveillance and the individuals' actions interact within the Environmental System of São Paulo State (Capítulo III). According to some interviewees, environmental complaint is a very effective practice to improve the law enforcement since the EMP recognizes the reduced surveillance infrastructure which does not cover the entire region, effectively. Based on a testimony of one interviewee, the cell phones are the "best friends" of nature due to the fact that

[16] http://www.aguasdabocaina.com.br/projeto.html.

"everybody has one", even in rural areas; thus every time that somebody see some potential environmental crime they can call the EMP and file a report of a violation.

There is a generalized awareness in the countryside of Bananal, Taubaté and Paraibuna about the legal measures if somebody commits an environmental crime such as deforestation. The ninety interviewees affirmed that in the last three years they had not seen deforestation take place. Some of them recognize deforestation actions in past years in their properties and they were charged by public institutions to repair the damages, according to the environmental legislations. Inside rural properties the only source of timber to build fences, barns, houses and every kind of wood structure comes from eucalyptus trees, according to the survey.

Figure 4.5 represents a prepared land for crop in the Paraibuna countryside. In the middle of the prepared land are seen some young trees. According to some farmers and local people, this is a different behavior than that observed in the past, when farmers used to clean the entire area to crop without keeping any trees inside. This new attitude is motivated by precautionary behavior in order to avoid environmental crimes, because there is the perception of the risk of environmental reporting followed by EMP surveillance, with potential law enforcement and penalties (Capítulo III), but also, as pointed by Farinaci (2012) there is a will to respect the legislation motivated by moral principles and growing environmental awareness. According to the Atlantic Forest Law (Law n^0 11.428 of 2006), the deforestation, suppression or exploitation of a natural vegetation without legal authorization is an environmental crime. Thus, ensuring law enforcement by individuals' actions in reporting crimes is a critical component to the forest governance in the Valley.

Figure 4.5. Paraibuna rural area. The arable land is ready to be use for crop production, however, some trees were left in the field due to the landowner's decision to not cut them.

4.2.3.3 Institutional Analysis and Development framework

The changes in the governance system promoted by the constitution of 1988, the spreading ideas of conservation since the 1980s, allied with the development of the Brazilian environmental legislation, the operation of the Environmental System of São Paulo State and society's engagement in order to promote environmental protection, has resulted in net forest gains and deforestation control. To the case study, the society interacts with public policies ensuring law enforcement through environmental complaint by citizens. As soon as the individuals realize the operation of the system via the consequences of legal punishment the system gives feedback to individuals, then increasing the individuals' trust in the public policy, strengthening environmental complaint as a positive act (Figure 4.6). Ostrom *et al.* (1994) call attention to the fact that self-monitoring can lower rule-breaking behavior but never eliminate it. Nonetheless, the individuals develop more comprehensive view of legislation system changing its attitudes motivated by precautionary behavior, decision to respect the legislation and by environmental awareness.

4.3 Ecosystem services and biodiversity

The forests' importance encompasses the maintenance of livelihoods, economic benefits, climate control and a number of ecosystem services (Moran and Ostrom 2010; Azevedo *et al.* 2014; Fenning 2014). Landowners' perception of ecosystem services is relative to their own experiences and practices and they do not necessarily recognize the same services or forest benefits highly prized by scientists (Silvano *et al.* 2005). In this research, seventy-five interviewees recognized at least one benefit provided by forests. The services related with water security and wildlife was highly recognized. 80% of the answers pointed out the forests' importance to water production and maintenance, and 58% recognize the needs of forest to preserve wildlife.

According to the interviewees' answers, they are more prone to recognize changes in wildlife than in water production and maintenance, as a phenomenon related to the forest regeneration in the Valley. This trend may be more prominent due to the sightings of mammals and birds in quantity and specie richness compared to their historical memory of the region, as they highlighted. At this point we should consider the Law of Environmental Crimes (n^0 9605 of 1998) that may be affecting the controlling of hunting activities and then influencing the patterns of wildlife geographical distribution and its population dynamics. However, recent research about biodiversity in Atlantic Forest reveal a decline in fauna leading the tropical forest remnants to critical conservation levels (Canale *et al.* 2012; Galetti and Dirzo 2013; Dirzo *et al.* 2014).

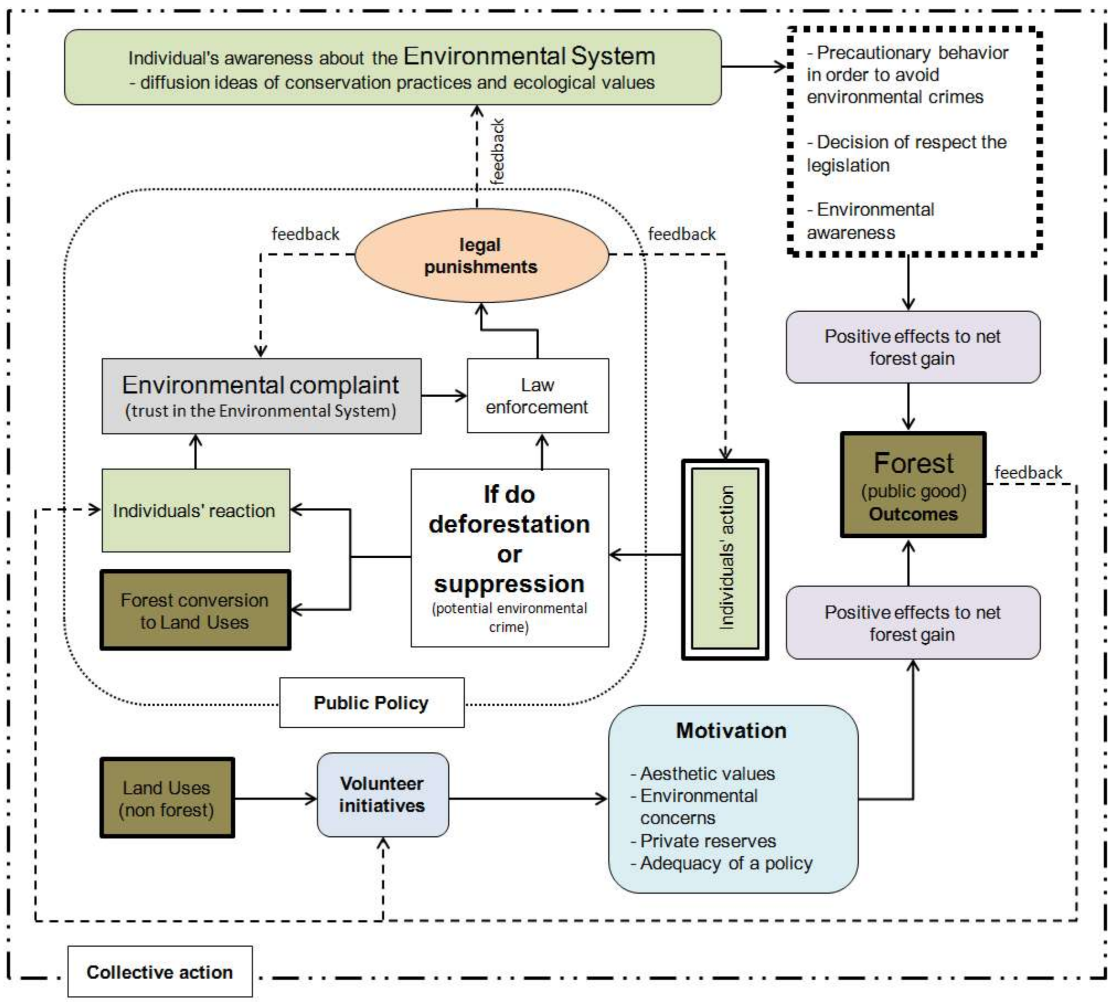

Figure 4.6. Institutional Analysis and Development framework. The collective action pathway of forest transition in the Paraíba Valley, São Paulo State.

The scientific evidences about biodiversity scarcity contradict the farmers' perception about the wildlife associated with the Atlantic forest fragments in the Paraíba Valley. Nonetheless, Silvano *et al.* (2005) has indentified which landowners' perception about environmental quality used to be an overestimation of the reality. Thus, the new forest areas are not necessarily indicative of the Atlantic forest ecological or faunal restoration (Teixeira *et al.* 2009), but the new forest areas have potential to reduce the isolation among fragments, increase the amount of original biodiversity (Lira *et al.* 2012), restore hydrological process and carbon storage.

4.4 A look into the future

The forest transition in the Paraíba Valley proves to be a process driven by socioeconomic changes allied to environmental features of its landscape and institutional frameworks. We assume that the spatial configuration of future forest cover and other land uses are directly related to the expectations of the landowners. To access the expectations about the future of rural areas in the region, two questions were addressed: the first to identify future trends of land use (*e.g.,* new land use cycles, expansion of eucalyptus plantations, decrease in agro-livestock activities), and the second to capture expectations about rural population dynamics. Among the ninety interviewees 51% expect the diminishing of agro-forestry-livestock activities while 40% expect the maintenance of the current standard. 9% of the interviewees have expectations of new rural cycles or the increase of the current activities. In relation to population dynamics, sixty nine interviewees affirmed that rural population with job not related to rural activities or retired will increase. According to the interviewees' perspective there is a migration wave from urban to rural areas motivated by expectations of better living conditions, economic advantages once rural areas are less expensive than urban areas, and in some cases the searching for a simple way of life. This population dynamic can be seen in Paraibuna due to the increase of rural population in the last decades. Most of these people in Paraibuna are settled in rural villages where there are schools, marketplaces, religious temples, and connected to the urban center by paved roads.

The future perspectives suggest a scenario with low expectations of massive investments in rural activities or in the development of new agro-forestry-livestock cycles. Thus, taking into account the present scenario of each municipality and the major trend of forest cover increase – forest regeneration replacing former pasturelands in terrain dominated by steep slopes (Capítulo I; Capítulo III) – the next decades is expected a continuous increase of new forest areas. These areas (slope classes above 20% over pasturelands) in Bananal represent 19286 ha, 17985 ha in Paraibuna and 18597 ha in Taubaté. Considering the same scenario to the Paraíba Valley region, the increment of new forest areas could reach 435345 ha or 30% of the Valley.

On the other hand, deforestation can compromise the perspectives of forest cover increase. According to the surveyed group, thirty four interviewees that recognized potential hazards to the forest cover areas and to the regeneration process, 85% of them answered that fire use by property holders as the most prominent hazard.

5. Conclusion

Bananal, Paraibuna and Taubaté presented net forest gain in recent decades. Despite of this fact, the three municipalities occupy different geographic locations in the Paraíba Valley, which influenced their economic development and population dynamics. Due to the similar topography, historical land uses and rural activities these municipalities converged to a common rural socioeconomic situation. The process of agricultural modernization and economic development aggravated the rural socioeconomic situation of the Valley. As a result of this scenario forest regeneration processes were observed over former pasturelands and agricultural areas. The natural forest regeneration is the major process of forest cover increase and highlights the Atlantic forest resilience capacity. Therefore, agricultural modernization takes on important role acting contemporaneously with the economic development pathway.

Voluntary actions of forest restoration are important once the human decision about land use has the power to determine future scenarios. The level of formal education suggested a positive rate between volunteer actions of forest restoration and high education level. Thus, the governments should consider investments in education as a strategy to boost biological conservation practices, as well as preparing the labor force of tomorrow. The individuals' attitude, to the case of Paraíba Valley deforestation control, results in a participatory process where the individuals engage in volunteer actions to ensure the law enforcement through environmental complaint of environmental crimes. Thereby, we suggest the collective action pathway, which encompasses all individuals' attitude to produce public goods, in the study case – increase forest cover areas.

Modern agriculture is knowledge-based (Vieira Filho 2014). Among the dairy farmers (the most important rural economic activity) 78% use some kind of modern management techniques such as semi-confinement, rotation and/or adapted and more productive breeds of dairy cattle. There is awareness in the countryside about the needs to modernize rural activities-- or the rural property will perish. On the other hand 91% of the interviewees have no expectations of improvements in the region's rural production systems. Therefore, we conclude that forest transition in the Paraíba Valley is a process that will continue its current positive course.

References

Ab'Saber, Aziz Nacib. (2003). Os domínios de natureza no Brasil: potencialidades paisagísticas [The Natural Areas of Brazil: landscape potentialities]. São Paulo: Ateliê Editorial, 6ªed.

Aggarwal, Charu C. (2013). Outlier Analysis. New York: Springer.

Ango, T. G., Borjeson, L., Senbeta, F., Hylander, K. (2014). Balancing Ecosystem Services and Disservices: Smallholder Farmers’ Use and Management of Forest and Trees in an Agricultural Landscape in Southwestern Ethiopia. Ecology and Society 19(1).

Areal, F. J., Riesgo, L. (2014). Farmers' views on the future of olive farming in Andalusia, Spain. Land Use Policy 36: 543–553.

Azevedo, J. C., Perera, A. H., Pinto, M. A., eds. (2014). Forest Landscapes and Global Change: Challenges for Research and Management. New York, Heidelberg, Dordrecht, London: Springer.

Balsan, R. (2006). Decurrent impacts of the agriculture modernization in Brazil. Campo-Território 1(2): 123–151.

Baptista, S. R. (2008). Metropolitanization and Forest Recovery in Southern Brazil: a Multiscale Analysis of the Florianópolis City-Region, Santa Catarina State, 1970 to 2005. Ecology and Society 13(2).

Beilin, R., Lindborg, R., Stenseke, M., Pereira, H. M., Llausas, A., Slätmo, E., Cerqueira, Y., Navarro, L., Rodrigues, P., Reichelt, N., Munro, N., Queiroz, C. (2014). Analysing how drivers of agricultural land abandonment affect biodiversity and cultural landscapes using case studies from Scandinavia, Iberia and Oceania. Land Use Policy 36: 60–72.

Beven, K. J., Kirkby, M. J. (1979). A physically based, variable contributing area model of catchment hydrology. Hydrology Sciences-Bulletin 24: 43–69.

Borba, M. F. S., Gomes, J. C. C. (2006). Desenvolvimento rural de Zonas Marginais [Rural development of marginal zones]. Ver. Bras. De Agroecologia 1(1): 1685–1688.

Borgonovi, M., Chiarini, J. V., Amaral, A. Z., Coelho, G. S., Oliveira, D. A. (1967). Cobertura Vegetal do Estado de São Paulo [Vegetal Cover of São Paulo State]. Bragantia 26(6): 95–102.

Buainain, A. M., Alves, E., Silveira, J. M., Navarro, Z., eds. (2014). O Mundo rural no Brasil do século 21 [The rural world of Brazil in the 21th Century]. Brasília: EMBRAPA.

Campbell, B. M., Gordon, I. J., Luckert, M. K., Petheram, L., Vettes, S. (2006). In search of optimal stocking regimes in semi-arid grazing lands: One size does not fit all. Ecological Economics 60(1): 75–85.

Canale, G. R., Peres, C. A., Guidorizzi, C. E., Gatto, C. A. F., Kierulff, M. C. M. (2012). Pervasive Defaunation of Forest Remnants in a Tropical Biodiversity Hotspot. PLOS One 7(8): e41671.

Carvalho, P. G., Oliveira, S. M. M. C., Barcellos, F. C., Assis, J. M. (2005). Gestão Local e Meio Ambiente [Local Management and the Environment]. Ambiente e Sociedade 8(1): 121–140.

Chazdon, R. (2012). Tropical Forest Regeneration. Bol. Mus. Pará. Emílio Goeldi. Cienc. Nat.7(3): 195–218.

Cramer, V. A., Hobbs, R. J., Standish, R. J. (2008). What's new about old fields? Land abandonment and ecosystem assembly. Trends in Ecology & Evolution 23: 104–112.

Dean, W. (1996). A Ferro e Fogo: História de uso e ocupação da Mata Atlântica [With Broadax and Firebrand: The Destruction of the Brazilian Atlantic Forest]. São Paulo: Cia. das Letras.

Dirzo, R., Yong, H. S., Galetti, M., Ceballos, G., Isaac, N. J. B., Collen, B. (2014). Defaunation in the Anthropocene. Science 345(6195): 401–406.

Editorial. (2014). Folha de São Paulo: Divisor de Águas [Turning point], December, 1555683.

Eskinazi, B. G., Souza, J. G. (2013). Expertise production and territorial Homogenization: eucalyptus monoculture in the Paraíba Valley and production dynamic changes. Mundo do Trabalho 14(2): 194–211.

Farinaci, Juliana Sampaio. (2012). "As novas matas do Estado de São Paulo": um estudo multiescalar sob a perspectiva da teoria da Transição Florestal [The new forests of São Paulo State: a multiscalar study on the Forest Transition Theory perspective]. Ph.D. dissertation, Department of Environment & Society, University of Campinas, Campinas.

Farinaci, J. S., Batistella, M. (2012). Variation on native vegetation cover in São Paulo: an overview of current knowledge. Revista Árvore 36(4): 695–705.

Farinaci, J. S., Ferreira, L. C., Batistella, M. (2013). Forest Transition and Ecological Modernization: eucalyptus forestry beyond good and bad. Ambiente & Sociedade 16(2): 25–44.

Fenning, Trevor, ed. (2014). Challenges and Opportunities for the World´s Forest in the 21st Century. Edinburgh: Springer.

Fibria. (2014). Relatório de Sustentabilidade 2013 [2013 Report of Sustainability]. São Paulo: Fibria.

Foley, J. A., Defries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T., Daily, G. C., Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kuvharik, C. J., Monfreda, C., Patz, J. A., Prentice, I. C., Ramankutty, N., Snyder, P. K. (2005). Global consequences of land use. Science 309(5734): 570–574.

Funcate. (2012). Emissões do setor de uso da terra, mudanças do uso da terra e florestas: relatório de referência/FUNCATE, CETESB [GHG Emissions from Land Use, Land-Use Change, and Forestry Sector in São Paulo State]. São Paulo: CETESB.

Galetti, M., Dirzo, R. (2013). Ecological and evolutionary consequences of living in a defaunated world. Biological Conservation 163: 1–6.

Garcia, J. R. (2014). Trabalho rural: tendências em face das transformações em curso [Rural work: trends in the face of the ongoing transformations]. *In* O Mundo rural no Brasil do século 21 [The rural world of Brazil in the 21th Century]. Buainain, A. M., Alves, E., Silveira, J. M., Navarro, Z., eds. Pp. 559–590. Brasília: EMBRAPA.

Godar, J., Gardner, T. A., Tizado, E. J., Pacheco, P. (2014). Actor-specific contributions to the deforestation slowdown in the Brazilian Amazon. PNAS 111(43): 15591–15596.

Grau, H. R., Aide, M. (2008). Globalization and Land-Use Transitions in Latin America. Ecology and Society 13(2).

Gray, C. L., Bilsborrow, R. E. (2014). Consequences of out-migration for land use in rural Ecuador. Land Use Policy 36: 182–191.

He, J., Lang, R., Xu, J. (2014). Local Dynamics Driving Forest Transition: Insights from Upland Villages in Southwest China. Forests 5: 214–233.

Helfand, S. M., Pereira, V. F., Soares, W. (2014). Pequenos e médios produtores na agricultura brasileira: situação atual e perspectivas [Small and medium agro-producers in Brazil: current situation and prospects]. *In* O Mundo rural no Brasil do século 21 [The rural world of Brazil in the 21th Century]. Buainain, A. M., Alves, E., Silveira, J. M., Navarro, Z., eds. Pp. 533–558. Brasília: EMBRAPA.

Hu, J., Si, Y., Zhou, D., Um, J., Li, J., Liu, L., Zhu, C., Deng, Y., He, J., Zhang, N., Chen, X. (2014). Prevalence and treatment gap of active convulsive epilepsy: A large community-based survey in rural West China. Seizure 23: 333–337.

IBGE (Instituto Brasileiro de Geografia e Estatística). (2010). Censo Demográfico 2010 [2010 Population Census]. Rio de Janeiro: IBGE.

Irwin, E. G., Geoghegan, J. (2001). Theory, data, methods: developing spatially explicit economic models of land use change. Agriculture Ecosystems & Environment 85: 7–23.

Itani, M. R., Barros, C. M., Figueiredo, F. E. L., Andrade, M. R. M., Mansor, M. T. C., Mangabeira, R. L., Carvalho, V. S., eds. (2011). Subsídios ao planejamento ambiental: Unidade de Gerenciamento de Recursos hídricos Paraíba do Sul [Subsidies for Environmental Planning: Hydrographic Unit Water of Resources Management of Paraíba do Sul]. São Paulo: SAM.

Kizos, T., Koulouri, M. (2006). Agricultural landscape dynamics in the Mediterranean: Lesvos (Greece) case study using evidence from the last three centuries. Environmental Science & Policy 9: 330–342.

Koontz, T. M. (2010) Money Talks? But to Whom? Financial Versus Nonmonetary Motivations in Land Use Decisions. Society & Natural Resources: An International Journal (14)1: 51–65.

Kush, G. S. (2001). Green revolution: the way forward. Nature Reviews/Genetics 2: 815–822.

Lambin, E. F., Meyfroidt, P. (2010). Land use transitions: Socio-ecological feedback versus socio-economic change. Land Use Policy 27(2): 108–118.

Lepsch, I. F., Bellinazzi Jr, R., Bertolini, D., Espíndola, C. R. (1991). Manual for Utility Survey of the Physical Environment and Land Classification by the System of Land Use Capacity, 4th ed. Campinas: Brazilian Society of Soil Science.

Lira, P. K., Tambosi, L. R., Ewers, R. M., Metzger, J. P. (2012). Land-use and land-cover change in Atlantic Forest landscapes. Forest Ecology and Management 15: 80–89.

Matson, P. A., Naylor, R., Ortiz-Monasterio, I. (1998). Integration of Environmental, Agronomic, and Economic Aspects of Fertilizers Management. Science 280: 112–115.

McGinnis, M. D. (2011). An Introduction to IAD and the Language of the Ostrom Workshop: A Simple Guide to a Complex Framework for the Analysis of Institutions and Their Development. School of Public and Environmental Affairs Research Paper Series No. 2011-02-01.

Minella, J. P. G., Merten, G. H. (2012). Topographic Index applied to Agricultural and Environmental Modelling. Ciência Rural 42(9): 1575–1582.

Moran, E. F., Ostrom, E., eds. (2005). Seeing the Forest and the Trees: Human-Environment Interactions in Forest Ecosystems. Cambridge: MIT Press.

Neske, M. Z., Almeida, J., Radomsky, G. F. W. (2013). Reinterpretando o desenvolvimento rural em "zonas marginalizadas" no Sul do Brasil: a contribuição dos estudos pós-coloniais [Reinterpreting the rural development in "marginalized areas" in southern Brazil: the contribution of postcolonial studies]. Revista de Ciencias Sociales 26(32): 93–112.

Olson, Mancur. (1965). The Logic of Collective Action: Public Goods and the Theory of Groups. Cambridge: Harvard University Press.

Ostrom, E., Gardner, R., Walker, J. (1994). Rules, Games, & Common-Pool Resources. Ann Arbor: The University of Michigan Press.

Ostrom, E. (1998). A Behavioral Approach to the Rational Choice Theory of Collective Action: Presidential Address, American Political Science Association, 1997. The American Political Science Review 92(1): 1–22.

Ostrom, Elinor. (2005). Understanding Institutional Diversity. Princeton: Princeton University Press.

Ostrom, E., Cox, M. (2010). Moving Beyond Panaceas: A Multi-Tiered Diagnostic Approach for Social-Ecological Analysis. Environmental Conservation 37(4): 451–463.

Ostrom, E. (2011). Background on the Institutional Analysis and Development Framework. Policy Studies Journal 39(1): 7–27.

Perz, S. G. (2007). Grand Theory and Context-Specificity in the Study of Forest Dynamics: Forest Transition Theory and Other Directions. The Professional Geographer 59(1): 105–114.

Roque, A. (2013). Estudo Preliminar da Cadeia Produtiva: Turismo Rural no Brasil [Preliminary Study of the Supply Chain: Rural Tourism in Brazil]. Brasília: IICA Brasil.

Rudel, T. K., Coomesb, O. T., Moran, E., Achardd, F., Angelsene, A., Xuf, J., Lambin, E. (2005). Forest transitions: towards a global understanding of land use change. Global Environmental Change 15: 23–31.

Salles-Filho, S., Bin, A. (2014). Reflexões sobre os rumos da pesquisa agrícola [Reflexions about the future of agricultural researches]. *In* O Mundo rural no Brasil do século 21 [The rural world of Brazil in the 21th Century]. Buainain, A. M., Alves, E., Silveira, J. M., Navarro, Z., eds. Pp. 423–452. Brasília: EMBRAPA.

Santana, A. C. (2008). Diversificação da agricultura familiar no Sul de Minas Gerais: uma análise de percepção de professores e pesquisadores [Diversification of family farming in southern Minas Gerais: A teachers' and researchers' perception analysis]. M.A. thesis, Department of Administration, Federal University of Lavras.

Silva, R. F. B., Ferraz, S. F. B., Sartori, A. A. C., Zimback, C. R. L. (2013). Integration of hydrologic processes for zoning agricultural landscapes: perspectives for ecosystem services maintenance. Journal of Environmental Science and Water Resources 2(8): 290–301.

Silvano, R. A. M., Udvardy, S., Ceroni, M., Farley, J. (2005). An ecological integrity assessment of a Brazilian Atlantic Forest watershed based on surveys of stream health and local farmers' perceptions: implications for management. Ecological Economics 53: 369–385.

Silveira, J. M. (2014). Agricultura brasileira: o papel da inovação tecnológica [Brazilian agriculture: the role of innovation]. *In* O Mundo rural no Brasil do século 21 [The rural world of Brazil in the 21th Century]. Buainain, A. M., Alves, E., Silveira, J. M., Navarro, Z., eds. Pp. 373–394. Brasília: EMBRAPA.

Sorensen, R., Zinko, U., Seibert, J. (2005). On the calculation of the topographic wetness index: evaluation of different methods based on field observations. Hydrology and Earth System Sciences Discussions 2: 1807-1834.

SOS Mata Atlântica, Fundação/INPE. (2014). Atlas dos remanescentes da Mata Atlântica período 2012-2013 [Atlas of the Atlantic Forest remnants, period of 2012-2014]. São Paulo: Fundação SOS Mata Atlântica/INPE.

Steffen, W., Grinevald, J., Crutzen, P., McNeill, J. (2011). The Anthropocene: conceptual and historical perspectives. Philosophical Transactions of the Royal Society A(369): 842–867.

Stotz, E. N. (2012). Limits of conventional agriculture and reasons for its persistence: a case study in Sumidouro, Rio de Janeiro, Brazil. Rev. bras. Saúde ocup. 37(125): 114–126.

Strijker, D. (2005). Marginal lands in Europe—causes of decline. Basic and Applied Ecology 6: 99–106.

Tabarelli, M., Pinto, L. P., Silva, J. M. C., Hirota, M. M., Bedê, L. C. (2005). Desafios e oportunidades para a conservação da biodiversidade na Mata Atlântica brasileira [Challenges and opportunities for biodiversity conservation in the Brazilian Atlantic Forest]. Megadiversidade 1(1): 132–138.

Teixeira, A. M. G., Soares-Filho, B. S., Freitas, S. R., Metzger, J. P. (2009). Modeling landscape dynamics in the Atlantic Rainforest region: Implications for conservation. Forest Ecology and Management 257: 1219-1230.

Tucker, C. M., Southworth, J. (2005). Processes of Forest Change at the Local and Landscape Levels in Honduras and Guatemala. In Seeing the Forest and the Trees: Human-Environment Interactions in Forest Ecosystems. Moran, E. F., Ostrom, E., eds. Pp. 253-277. Cambridge: MIT Press.

Urpelainen, J., Yoon, S. (2015). Solar home systems for rural India: Survey evidence on awareness and willingness to pay from Uttar Pradesh. Energy for Sustainable Development 24: 70–78.

Victor, M. A. M., Cavalli, A. C., Guillaumon, J. R., Serra Filho, R. (2005). Cem Anos de Devastação Revisitada 30 anos depois [One Hundred Years of Devastation Revisited 30 years later]. Brasília: MMA.

Vieira, E. T., Santos, M. J. (2012). Industrialização e desenvolvimento regional: política do CODIVAP no Vale do Paraíba na década de 1970 [Industrialization and regional development: CODIVAP policy in the Paraíba Valley in the 1970s]. Desenvolvimento Regional em Debate 2(2): 161–181.

Vieira Filho, J. E. R. (2014). Transformação histórica e padrões tecnológicos da agricultura brasileira [Historical transformation and technological Standards of the Brazilian agriculture]. *In* O Mundo rural no Brasil do século 21 [The rural world of Brazil in the 21th Century]. Buainain, A. M., Alves, E., Silveira, J. M., Navarro, Z., eds. Pp. 395–422. Brasília: EMBRAPA.

Washington-Ottombre, C., Pijanowski, B., Campbell, D., Olson, J., Maitima, J., Musili, A., Kibaki, T., Kaburu, H., Hayombe, P., Owango, E., Irigia, B., Gichere, S., Mwangi, A. (2010). Using a role-playing game to inform the development of land-use models for the study of a complex socio-ecological system. Agricultural Systems 103: 117–126.

Zuquim, M. L. (2007). Os caminhos do rural: uma questão agrária e ambiental [The rural paths: an agrarian and environmental question]. São Paulo: SENAC.

Principais destaques da tese

(i) A topografia de “mares de morros” caracterizada por relevos acentuados, com declives acima de 20% cobrindo 63% da região, representou e ainda representa fator decisivo de restrição às atividades agropecuárias modernas e de maior escala que a agricultura tradicional. Esta característica favoreceu a diminuição da importância econômica rural da região com a consequente diminuição da pressão sobre o uso da terra, seguida pelo retorno da vegetação florestal em antigas áreas de uso agropecuário. Atualmente, esta relação entre uso da terra e topografia tem surtido efeitos sobre a dinâmica de expansão da eucaliptocultura, que se encontra estagnada nesta área específica, enquanto em ascensão em outras regiões brasileiras.

(ii) Entre os anos de 1962 e 2011, a cobertura florestal nativa valeparaibana passou de 225 mil para 446 mil hectares, crescimento de 98%, sendo a proximidade aos remanescentes florestais o fator mais importante para o processo de regeneração desta cobertura.

(iii) O eucalipto exerceu maior pressão de desmatamento nas primeiras décadas de seu estabelecimento na paisagem valeparaibana, porém com mudança nesta tendência nas últimas décadas. A associação do eucalipto com o desmatamento, entre 2005 e 2011, esteve restrito às áreas de formações sucessivas iniciais, com idades inferiores a dez anos, que indica redução da pressão exercida pela expansão desta cultura sobre os remanescentes da Mata Atlântica.

(iv) A relação dos plantios florestais de eucalipto, com a produção de celulose comercializada majoritariamente no mercado internacional europeu, exigiu a adequação do mercado produtor aos selos de certificação de responsabilidade socioambiental, entre eles o FSC e o Cerflor. Esta situação favoreceu o aumento de resiliência da Mata Atlântica, medido através dos índices positivos de crescimento de floresta próximo às áreas de influência dos plantios de eucalipto. Na perspectiva de transição florestal esta relação pode ser explicada pela via da Globalização. O controle dos incêndios florestais (plantios de eucalipto), promovido pela indústria do papel e celulose, também deve ser visto como elemento positivo na relação entre

florestas naturais e eucaliptocultura, uma vez que o fogo é um importante vetor de degradação e perda de resiliência da Mata Atlântica.

(v) 91% dos entrevistados em propriedades rurais (n total = 90 indivíduos) não demonstraram expectativas de crescimento da produção agropecuária na região ou a entrada de novos ciclos para o uso da terra. Considerando a informação anterior de que a decisão humana sobre o uso da terra tem o poder de determinar cenários futuros, a tendência identificada para 435.345 hectares (pastagens sobre relevos acima de 20% de declive), ou 30% do Vale, é o restabelecimento da cobertura florestal.

(vi) Entre os proprietários de terras que adotaram iniciativas voluntárias de reflorestamento, 12% não tinham nível formal de educação; 7% o básico; 33% o ensino médio e 46% o nível superior. Assim, os resultados sugerem que quanto mais elevado o nível de educação formal, mais provável a adoção de iniciativas de reflorestamento. Desta forma, os governos deveriam considerar os investimentos em políticas educacionais como estratégia para aumentar as práticas de conservação biológica.

(vii) Em relação à via da modernização agrícola para a transição florestal, a questão fundamental foi o processo de marginalização da zona rural valeparaibana em relação ao contexto nacional, que favoreceu a diminuição das atividades agropecuárias, dada sua baixa competitividade. Esta relação ocorreu com o ciclo do café, com a pecuária, agricultura e agora, observa-se com o eucalipto. O processo de marginalização da zona rural traz diminuição da pressão sobre o uso da terra e abre oportunidade para a regeneração da floresta.

(viii) A transição florestal tende a ocorrer em áreas menos apropriadas para a agricultura, principalmente quando estas áreas estão disponíveis na paisagem. À medida que estas áreas são ocupadas pela cobertura florestal, forças socioeconômicas, como o crédito agrícola e o desenvolvimento econômico passam a desempenhar papel importante sobre os padrões espaço-temporais desta dinâmica, favorecendo o retorno das florestas onde há menor captação de crédito rural por área

ou naqueles municípios onde há maior concentração de estabelecimentos comerciais e industriais.

(ix) A atitude dos indivíduos, para o caso de controle ao desmatamento no Vale do Paraíba Paulista, resulta em um processo participativo, onde comunitariamente se envolvem em ações voluntárias para assegurar a aplicação da lei através da denúncia dos crimes ambientais. Nesse contexto, somado às ações voluntárias de reflorestamento, sugerimos a via da ação coletiva para a transição florestal, que engloba todas as atitudes dos indivíduos para a produção de bens públicos, que no caso em estudo, referem-se ao aumento das áreas de cobertura florestal.

(x) A crise hídrica vivenciada pela região, em parte resultado do processo histórico de uso e ocupação da terra, foi agravada com a escassez de chuvas entre os anos 2013-2014. Durante este período, diversas atividades agropecuárias foram severamente comprometidas, inclusive levando produtores à venda de rebanhos por falta de água para dessedentação animal. Como já apontado no item *v*, este quadro sugere um *feedback* sócio-ecológico negativo que surgiu a partir da depleção de um recurso chave (água), que poderá surtir efeitos positivos na transição florestal dos próximos anos.

Conclusões


Fotografia tirada em 2014, durante trabalho de campo. Local: Taubaté.

As classes de uso e cobertura da terra apresentaram comportamentos espectrais esperados estatisticamente, que foram expressos através de valores constantes de reflectância observados na série temporal, informação essencial para realizar a classificação multitemporal da série TM/Landsat-5 de imagens. Dentre os anos de mapeamento, 1985, 1995, 2005 e 2011, as pastagens foram o fator de uso da terra,que mais cederam espaço para o retorno da floresta, bem como para o estabelecimento dos plantios de eucalipto. Os dados de sensoriamento remoto foram fundamentais para o desenvolvimento da pesquisa sobre a transição florestal valeparaibana.

A modernização agrícola e o desenvolvimento econômico agravaram a situação socioeconômica rural do Vale do Paraíba Paulista e consequentemente a diminuição predatória sobre o uso da terra, liberando antigas áreas de uso agropecuário para a recuperação do ecossistema natural.

O eucalipto é o principal recurso madeireiro para a propriedade rural, para a construção civil, pontes, cercas, ferramentas e energia, uma vez que o uso de madeira nativa para estas finalidades tornou-se uma prática legalmente inviável. A restrição legal do corte e uso de madeira nativa da Mata Atlântica tem forçado a sociedade rural valeparaibana a usar o eucalipto como recurso madeireiro. Esta situação tem contribuído positivamente para a diminuição da pressão sobre a extração de madeira nativa, uma vez que o eucalipto é um recurso disponível na paisagem e a custos econômicos acessíveis para as propriedades rurais. Os mecanismos legais para proteger a Mata Atlântica têm contribuído positivamente para o aumento da cobertura florestal valeparaibana, como no caso acima mencionado, e especialmente porque as áreas degradadas em processos de regeneração (formações florestais em estágios de sucessão secundária) são consideradas parte da composição florestal do bioma; avanço alcançado desde 1993 através do Decreto Federal n^0 750. O processo de formulação de políticas públicas para a conservação e proteção do bioma Mata Atlântica, desde 1993 (Decreto Federal n^0 750), demonstra preocupação com a recuperação do bioma e não apenas com a conservação de seus remanescentes, uma vez que até o fim da década de 1980 restavam apenas cerca de 8% de suas formações florestais originais. Assim, conclui-se que a via da escassez florestal assume relevante poder expansionista sobre o caso valeparaibano, com potenciais repercussões sobre o bioma em nível nacional.

Os dados de crescimento da cobertura florestal sobre áreas hidrológicas mais sensíveis não demonstrou haver relação direta que indicasse o processo de recuperação das florestas, nas últimas décadas, orientado por preocupações com a conservação da água. Durante a pesquisa de campo às propriedades rurais, em 2014, a crise hídrica que assolava a região demonstrou ter influenciado a percepção dos entrevistados sobre a importância da cobertura florestal para a garantia de abastecimento hídrico. Também demonstrou ter influência sobre o interesse dos proprietários rurais em se comprometer com ações de reflorestamento, sobre tudo em nascentes.

Trinta e quatro entrevistados durante a pesquisa de campo a propriedades rurais (n total = 90 indivíduos) reconheceram riscos potenciais para a cobertura florestal e para o processo de regeneração. 85% deles responderam que o fogo é o risco mais proeminente. Com isso, conclui-se que o processo de transição florestal, agora em curso na região Valeparaibana, pode sofrer revezes que comprometam os ganhos em cobertura florestal das últimas décadas e os futuros. Este cenário de risco é especialmente agravado nos períodos de escassez de chuvas.

Diversas pesquisas têm demonstrado a complexidade da transição florestal nas mais variadas regiões do planeta, evidenciando uma variedade de possíveis vias ou caminhos a serem seguidos. Desta forma, fica claro que existem muitos contextos que moldam o modelo de TF observado em cada região particular. Isto significa que as condições locais, como o relevo, a qualidade do solo, o histórico de uso da terra, as políticas públicas, o engajamento da sociedade em fazer cumprir normas e acordos, a ação dos órgãos fiscalizadores, ações voluntárias de reflorestamento, assim como a relação de comércio entre a região produtora de um determinado produto ou commoditie com seus centros compradores, representam dimensões que combinadas, criam os contextos determinantes para as trajetórias de transição dos usos da terra e das florestas.

Figura síntese do processo de transição florestal

No período de tempo marcado pela recuperação da cobertura florestal, dados disponíveis desde 1962, em diversos momentos da história econômica e agrária no Brasil em níveis nacionais e regionais, bem como a realidade fática do mercado internacional de commodities, especificamente a celulose para o caso valeparaibano e a situação de escassez florestal, deram o suporte contextual a este processo. A figura síntese (Figura 9) traz, de maneira resumida, os caminhos e momentos da história que tiveram papel primordial para a recuperação da cobertura florestal no Vale do Paraíba. Entendo a TF como um processo temporal, sendo que a figura mostra momentos históricos e seu respectivo contexto para este processo. Espera-se que a crise hídrica atual tenha efeitos futuros sobre a transição florestal através da via do F*eedBack* sócio-ecológico.

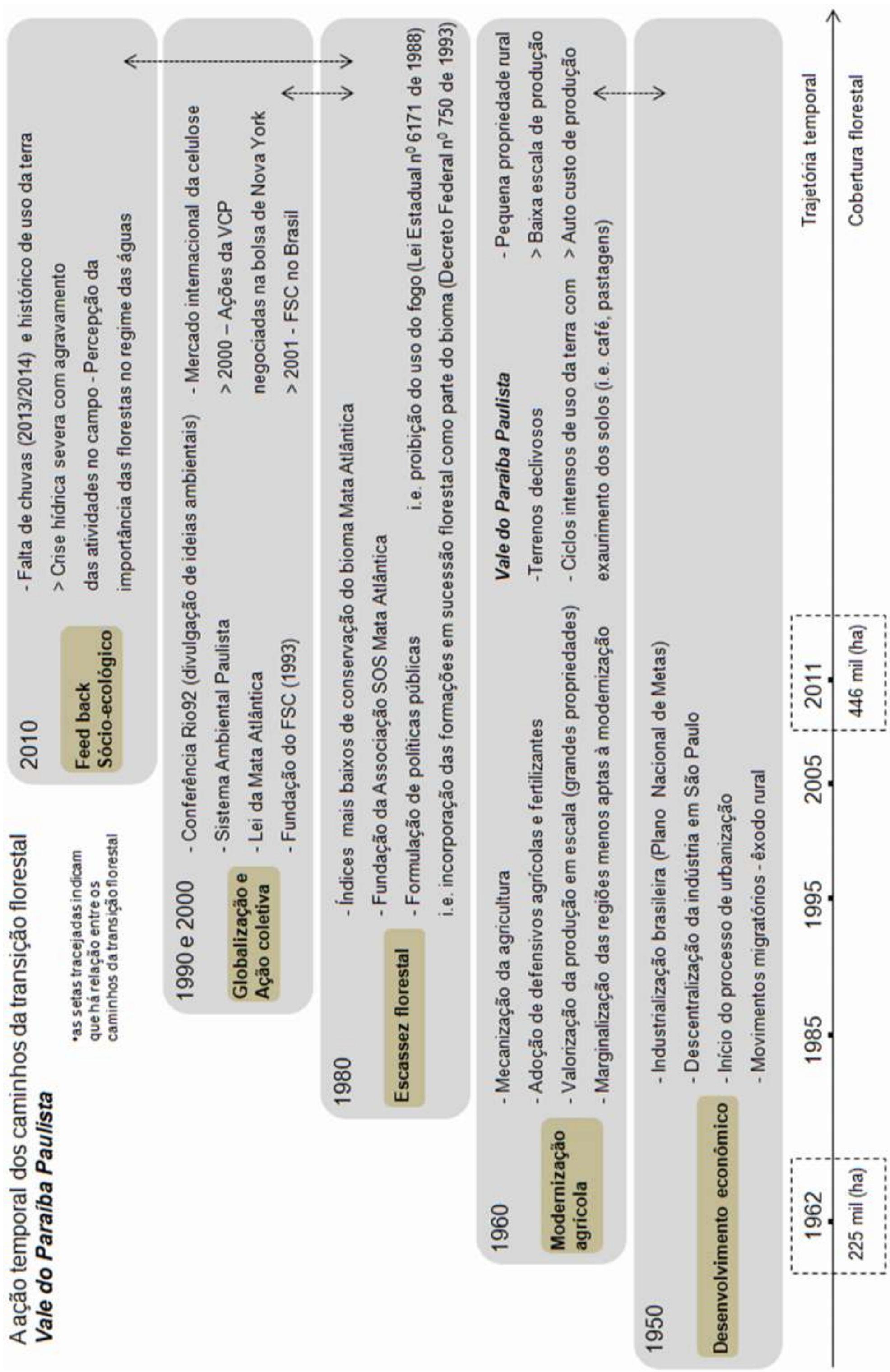

Figura 9. Síntese dos caminhos para a Transição Florestal Valeparaibana.

Visão da pesquisa

Considerações sobre a tese

A tese demostrou que o Vale do Paraíba Paulista está passando pelo processo de transição florestal. Este fato responde a pergunta central da pesquisa de doutorado: Sim, há transição florestal no Vale do Paraíba Paulista.

O objetivo central da tese, bem como os seus objetivos específicos foram alcançados, uma vez que para responder a pergunta de pesquisa, antes foi necessário classificar o uso e cobertura da terra, identificar as dinâmicas espaciais e temporais das mudanças nestes usos e coberturas com ênfase na cobertura florestal, além de compreender os contextos sociais, econômicos e biofísicos da paisagem, que condicionaram tais mudanças. As hipóteses se mostraram coerentes e assim puderam ser testadas e corroboradas através do desenvolvimento dos capítulos. A organização do documento da tese em capítulos, na forma de artigos científicos, se mostrou uma opção adequada para o desenvolvimento da pesquisa interdisciplinar que lidou com diversas frentes do conhecimento científico. Esta opção contribuiu positivamente com o desenvolvimento do trabalho de pesquisa, tornou clara a necessidade de abordagens metodológicas específicas e necessárias para alcançar cada objetivo da tese, e na organização teórico-metodológica dos conteúdos apresentados, que proporcionaram uma cadência lógica para a apresentação e discussão dos resultados ao longo do trabalho.

Após a conclusão das pesquisas de campo, através do volume de informações adquiridas e que possibilitaram compreender em profundidade os complexos padrões espaço-temporais do uso e cobertura da terra valeparaibana, tornaram inquestionáveis a necessidade das pesquisas in loco, ferramenta fundamental para a execução de análises interdisciplinares que se propõem a compreender os aspectos biológicos e sociais de conservação da biodiversidade.

A pesquisa interdisciplinar é um projeto que deve ser concebido a partir de perguntas simples que se tornam potencialmente complexas, à medida que os envolvidos reconhecem suas variadas dimensões. Dessa forma, uma pergunta simples é capaz de abranger um amplo espectro do mundo real. À medida que os envolvidos se propõem a respondê-la, percebem que para tal, se torna antes necessário compreender as múltiplas dimensões que compõem o problema objeto da pesquisa. Essas variáveis podem ser representadas pela cultura, economia, globalização, aspectos biofísicos e geográficos de uma determinada paisagem, religião, gênero, educação entre outras. Assim, responder à pergunta simples através de apenas uma das dimensões pode levar os envolvidos a uma pesquisa básica disciplinar. Já a escolha de compreendê-la a partir de suas variadas facetas, torna o caminho para sua resposta mais complexo e invariavelmente dependente de diversas áreas do saber; logo, à prática interdisciplinar.

Perspectivas e novas perguntas

A floresta Atlântica no Vale do Paraíba Paulista está retornando, fato notório e que merece atenção das autoridades públicas, cientistas e da sociedade. A respeito deste relevante fenômeno, também conhecido por transição florestal, existe a dimensão social, necessária para dar contexto ao fenômeno mencionado. Para o caso valeparaibano há particularmente um elemento que necessita especial atenção sobre este fenômeno, dada sua intrínseca relação com o uso da terra: o meio rural e seus modos de vida. Por esta razão, pensar o bioma Mata Atlântica se torna mais que pensar sua complexa dimensão ecológica ou mesmo sua incontestável importância no suprimento de serviços ecossistêmicos; é também pensar a dimensão social, que a séculos interage, usa e modifica-o de acordo com interesses econômicos, culturais e políticos.

É por esta perspectiva, de integração entre dimensão social e ambiental, que espero sermos capazes de tirar o melhor proveito do processo de regeneração florestal ao mesmo tempo em que a remanescente população rural também possa optar por este modo de vida, com o desenvolvimento de atividades agrícolas e pecuárias que os mantenham socioeconomicamente. O processo de transição florestal pela regeneração natural em áreas abandonadas é o mais frágil dos cenários, uma vez que novos ciclos econômicos podem demandar terras e consequentemente submeter à floresta regenerada, novos ciclos de desmatamento. Desta forma, compreender a dimensão social da transição florestal é fundamental para pensar estratégias de conservação ambiental e ao mesmo tempo lidar com as demandas de uso e ocupação da terra.

A respeito do futuro das paisagens valeparaibanas, é de se esperar que a cobertura florestal nas próximas décadas cresça aproximadamente 400 mil hectares. A pecuária extensiva e de baixa produtividade deixará de existir, restando apenas aquelas propriedades que investiram em tecnologia e intensificação. As zonas rurais estarão ainda mais interligadas às áreas urbanas, o que estimulará o aumento de moradores nestas regiões, sem com isso desenvolverem atividades econômicas agropecuárias. Florescerão as iniciativas de agricultura agroecológica, orgânica e de pequenas escalas voltadas aos mercados locais. A eucaliptocultura para papel e celulose estará restrita às propriedades particulares das próprias empresas e o eucalipto na propriedade rural terá outras finalidades, como para uso na movelaria, confecção de utensílios e construção civil. A eucaliptocultura não terá expansão territorial que seja expressiva em relação aos dados observados em 2011.

Esta pesquisa fecha algumas questões fundamentais, como se há ou não transição florestal no Vale do Paraíba, ou, como fatores sociais, econômicos e biofísicos interagiram com este fenômeno. No entanto, suas conclusões nos levam a novas e complexas questões: Como conciliar um modelo de ocupação e uso do espaço rural com a manutenção de áreas em processo de regeneração da floresta? Como garantir que a transição florestal não sofra revés? Quais poderão ser os novos ciclos do agronegócio a florescerem no Vale e quais serão seus impactos sobre os remanescentes da Mata Atlântica e sobre a biodiversidade?

Anexos

Anexo 1

Questionário estruturado aplicado no Capítulo III

INFORMAÇÕES GERAIS

Nome completo:

Tempo de atuação e experiência na região de estudo:

Qual o âmbito de atuação na região (municipal, UGRHI 02, sub-bacias, micro regiões):

Formação acadêmica/profissional:

Instituição/local de trabalho:

Entrevista estruturada

**Escolha apenas duas alternativas para cada pergunta*

(1) Quais Sao os fatores mais importantes para a diminuição da cobertura florestal (Mata Atlântica) no Vale do Paraíba entre as décadas de 1980 a 2010:

- ☐ café
- ☐ pecuária
- ☐ rodovias/eixos viários
- ☐ crescimento urbano/populacional
- ☐ silvicultura (papel e celulose)
- ☐ produção de energia (lenha e carvão)
- ☐ falta de fiscalização de órgãos públicos e descumprimento de leis ambientais
- ☐ agricultura (culturas anuais e perenes)
- ☐ mineração
- ☐ outro:____

(2) Quais Sao os fatores mais importantes para a diminuição das atividades agrícolas na região do Vale do Paraíba nas últimas décadas:

- ☐ dificuldade de acesso a crédito rural
- ☐ degradação social e ambiental dos sistemas agrícolas

☐ endurecimento e ineficiência das legislações ambientais e agrárias

☐ carência de assistência técnica extensionista

☐ desmantelamento dos sistemas de mercado e comércio de produtos locais/consolidação de grandes redes de comercialização de alimentos

☐ envelhecimento da população rural e escolha das gerações subsequentes pelo trabalho oferecido nas cidades/abandono de terras agrícolas

☐ outro:____

(3) Quais Sao os fatores mais importantes para o aumento da eucaliptocultura nas propriedades rurais do Vale do Paraíba nas últimas décadas:

☐ estabelecimento de plantas industriais de papel e celulose

☐ fonte de renda alternativa com garantia de comercialização

☐ "poupança verde" – investimento com garantia de retorno no futuro

☐ desoneração da mão de obra e não necessidade de trabalho diário intenso no manejo

☐ da cultura (maior oportunidade para o produtor se dedicar a outras atividades)

☐ investimento privado do setor industrial/ descapitalização do agricultor

☐ fomentos e acesso a créditos agrários/florestais

☐ alternativa de uso em áreas agrícolas degradadas com boa relação custo/benefício

☐ outro:____

(4) Quais Sao os fatores mais importantes para a estabilização das taxas de cobertura florestal (Mata Atlântica) no Vale do Paraíba a partir da década de 2000, considerando que a partir deste período Sao notadas as mais baixas taxas de desmatamento e real aumento da taxa de cobertura florestal para a região:

☐ consolidação de Unidades de Conservação com planos de manejo aprovados

☐ evolução da atividade industrial

☐ envelhecimento da população rural e escolha das gerações subsequentes pelo trabalho oferecido nas cidades/abandono das áreas rurais

☐ compensações ambientais/termos de ajustamento de conduta de atividades do setor privado e público

- [ ] certificação florestal (FSC) no setor da silvicultura
- [ ] mobilização da sociedade civil organizada/atividades voluntárias de recuperação florestal
- [ ] fiscalização de órgãos públicos e endurecimento das leis ambientais
- [ ] outro:____

Anexo 2

Questionário semiestruturado aplicado no Capítulo III

ENTREVISTA SEMIESTRUTURADA

(1) A partir de sua ótica; nas últimas décadas, como se deu o processo de degradação do bioma Mata Atlântica na região do Vale do Paraíba? Pensando nas últimas 3 décadas, qual foi ou ainda esta sendo, o mais importante ciclo de uso da terra e mudança ambiental nesta região?

(2) Considerando que a cobertura de Mata Atlântica chegou a níveis baixos no Vale do Paraíba Paulista, a diminuição das taxas de desmatamento e a recuperação desta cobertura podem ser consideradas um reflexo dos sistemas institucionais e de políticas públicas que interagem com a região? Se sim, quais regimes institucionais (ex: comitê de bacias, associações e institutos) ou políticas públicas (leis e normas) podem ser citadas?

(3) O reflorestamento (eucalipto) é um processo que tem ocorrido nas últimas décadas no Vale do Paraíba, no entanto não ocorre em mesmas proporções para todas as cidades que fazem parte desta região. O que pode explicar esta diferença? (ex: as distâncias das plantas industriais de papel e celulose, a não aceitação de plantios por determinados municípios ou comunidades rurais, capacidade agrícola das terras, declividade dos terrenos, proximidade de áreas urbanas, proximidade e maior acesso aos principais eixos viários).

(4) Qual a importância regional das UPAs no Vale para o suprimento de bens básicos, como alimentos e serviços ecossistêmicos?

(5) A estrutura ambiental dos municípios tem desempenhado papel importante no processo de controle da expanSao da eucaliptocultura e nos outros usos da terra e no combate a desmatamentos?

(6) Há indícios de novos processos de expanSao de culturas agrícolas, florestais ou de obras de infra-estrutura que podem comprometer os remanescentes florestais existentes na bacia do Vale do Paraíba?

(7) Qual foi ou quais foram as mudanças no perfil socioeconômico da zona rural no Vale, sobre tudo para as famílias e propriedades que migraram para a produção de eucalipto? Há diferenças significativas entre os sistemas de negócio (tipos de contratos) entre os produtores com as empresas do setor florestal?

(8) A pecuária continua sendo uma atividade econômica importante para a região? Pecuária leiteira ou de corte? Em relação à pecuária, é possível dizer que existe uma diferença importante nos modos de manejo entre a pecuária de corte e de leite? Se existem diferenças, estas podem ser relacionadas à dinâmica do uso da terra, como por exemplo: expanSao de novas áreas de pastagens; abandono de terras (pastagens) ou outras dinâmicas?

(9) É possível reconhecer o fenômeno de abandono de terras na região? Se sim, qual ou quais podem ser os fatores mais importantes para este fenômeno? Existe algum grau de correlação entre o abandono das terras e a volta de vegetação florestal no Vale do Paraíba?

(10) Qual é a legislação ambiental mais importante para o controle e fiscalização da região do Vale do Paraíba?

(11) Pensando na questão do abandono da terra, nos sucessivos processos de formação de pastos sujos e mesmos estágios iniciais de florestas, na diminuição da pecuária leiteira, aumento do número do rebanho de gado para corte e na atuação da legislação ambiental sobre a região, como pode ser avaliado o processo de formação de novos fragmentos florestais, abertura de novas áreas de pastagens e controle do crescimento vegetacional em pastos e áreas abandonadas?

(12) Qual é a sua perspectiva para a dinâmica territorial no Vale do Paraíba para os próximos 30 anos? É possível pontuar um novo ciclo agroeconômico a despontar neste período ou os padrões dos próximos 30 anos seguirão os mesmos hoje observados?

Anexo 3

Questionário estruturado para o Capítulo IV

Questionário de pesquisa para o estudo da dinâmica das Florestas no Vale do Paraíba, Estado de São Paulo – Brasil

Realização: UNICAMP

Apoio FAPESP, processo n^0 2011/13568-0

Responsável: Ramon Felipe Bicudo da Silva

Identificação

Profissão/ocupação:

Idade: sexo:

Nível de escolaridade

[ ] Fundamental incompleto	**[ ]** Médio incompleto	**[ ]** Superior incompleto
[ ] Fundamental completo	**[ ]** Médio completo	**[ ]** Superior completo

É produtor rural?

[ ] Sim [ ] Não

Reside na propriedade rural?

[ ] Sim **[ ]** Não

Possui renda exclusiva da atividade rural?

[ ] Sim **[ ]** Não

Qual é a principal atividade rural?

Tamanho da propriedade

O senhor(a) acredita que houve crescimento das matas na sua propriedade ou na sua região?

[ ] Sim **[ ]** Não

Se a resposta é Sim, siga para as próximas perguntas, por favor.

Se a resposta é Não, explique porque, por favor.

1. O que tem contribuído para o crescimento das matas, ao invés das mudanças destas matas para outros usos da terra ou o desmatamento?

Leis ambientais? [ ] Sim [ ] Não	**Como estas leis podem funcionar na região?**
[ ] Proibição da queimada	**[ ]** Fiscalização dos órgãos públicos
[ ] Proibição ao desmatamento	**[ ]** Denúncias da população
[ ] Unidades de conservação	**[ ]** Decisão de respeitar as leis
[ ] Proibição da caça	**[ ]** Outra
[ ] Código florestal (Reserva Legal e APP)	

Situação socioeconômica do meio rural?	**Porque?**
[ ] Sim **[ ]** Não	**[ ]** Envelhecimento da população rural
	[ ] Solos degradados e com baixas condições para a agropecuária
	[ ] Desinteresse pelo trabalho/atividade rural
	[ ] Busca por melhores condições de vida nas cidades
	[ ] Oferta de emprego nas cidades
	[ ] Falta de mão-de-obra na zona rural
	[ ] Outra

As matas só crescem em lugares impróprios para agricultura e pecuária, por isso são abandonadas?
[ ] Sim **[ ]** Não
*Se sim, onde:

Existe expectativa de ganhos econômicos ($) com as matas em pé?
[ ] Sim **[ ]** Não

Se houve crescimento das matas, foi uma escolha voluntária?

[ ] Sim **[ ]** Não	**Porque?**
	[ ] Beleza paisagística
	[ ] Preocupação com o meio ambiente
	[ ] Outras

Entrada do eucalipto na propriedade rural?

[ ] Sim **[ ]** Não	**Porque?**
	[ ] Certificação ambiental
	[ ] Diminuição ou abandono da atividade agropecuária
	[ ] Maior fiscalização nas áreas de eucalipto
	[ ] Outras

2. Há algum benefício direto ou indireto percebido com o retorno das matas?

[ ] Sim **[ ]** Não

Quais são os benefícios?

[ ] Produção de água

[ ] Controle de erosão

[ ] Mudança no clima local

[ ] Econômico

[ ] Maior abundância de aves e outros animais

[ ] Paisagem mais bonita e agradável

[ ] Atração de visitantes, turismo

[ ] Resgate de tradições culturais, lendas e mitos

[ ] Outros

3. Existe alguma possibilidade para que o processo de recuperação das matas pare?

[ ] Sim **[ ]** Não

Porque?

[ ] As áreas de florestas já estão perto de atingir um limite que começará a entrar em conflito com a agropecuária

[ ] A especulação imobiliária e o valor econômico da terra podem influenciar a decisão de impedir o retorno da floresta onde ela ainda não esta presente, e desta forma garantir o uso destas terras em possíveis negócios futuros

[ ] Outras

4. Há demanda de madeira da mata nativa para fogo, energia ou cerca?

[ ] Sim **[ ]** Não

Eucalipto? [ ] Sim [ ] Não

5. Quais são as áreas menos aptas para a atividade rural agrícola ou agropecuária?

[ ] Áreas com relevo muito acentuado

[ ] As contra-faces dos morros

[ ] Áreas com solos e pastagens degradadas

[ ] Margens de cursos d´água

[ ] Áreas mais distantes na propriedade rural, de difícil acesso

[ ] Outras

6. Quais são as perspectivas futuras para a agropecuária no Vale do Paraíba?

[ ] Entrada de novos ciclos do agronegócio

[ ] Expansão da eucaliptocultura

[ ] Manutenção da situação atual

[ ] Agricultura orgânica/agroecologia

[ ] Intensificação da pecuária/pastejo rotacionado

[ ] Queda de produtividade dos sistemas agropecuários

[ ] Aumento de produtividade dos sistemas agropecuários

[ ] Maior apoio dos órgãos de extensão e assistência rural

[ ] Diminuição das atividade rurais agrícolas e pecuárias

[ ] Outras

7. Qual é o futuro do modo de vida rural Valeparaibano?

[ ] Continuação do declínio populacional da zona rural

[ ] Estabilização da população rural

[ ] Aumento da população rural

[ ] Maior concentração de moradores com renda independente do uso agropecuário da terra

[ ] Aumento da agricultura familiar

[ ] Outros