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VOLUME 24

ISSUE 1

VERSION 1.0



GLOBAL JOURNAL OF HUMAN-SOCIAL SCIENCE: B
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MANAGEMENT

VOLUME 24 ISSUE 1 (VER. 1.0)

OPEN ASSOCIATION OF RESEARCH SOCIETY

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GEOGRAPHY, GEO-SCIENCES, ENVIRONMENTAL SCIENCE & DISASTER
MANAGEMENT

Volume 24 Issue 1 Version 1.0 Year 2024

Type: Double Blind Peer Reviewed International Research Journal

Publisher: Global Journals

Online ISSN: 2249-460X & Print ISSN: 0975-587X

Mapping and Characterization of Physical-Natural Units in the Municipality of Massapê - Ceará, Brazil

By Vanessa Campos Alves, José Falcão Sobrinho, Simone Ferreira Diniz, Bruna Lima Carvalho, Rejane Maria Lima de Sousa & Nayane Fernandes

Universidade Estadual Vale do Acaraú/UVA

Abstract- The research "Mapping and Characterization of the Physical-Natural Units of the Municipality of Massapê, Ceará" aims to shed light on the geographical and environmental richness of the backcountry region of northeastern Brazil, exploring the complexity of the northeastern hinterland. In this way, it covers the mapping of physical-natural units in the municipality of Massapê, in the state of Ceará, considering its importance for territorial planning and environmental management, the characterization of the nature of the municipality allows the understanding of the dynamics and interactions between the environment and the human activities, providing relevant data for preservation and sustainable development strategies. It is concluded that the research contributes significantly to the integrated understanding of the geographic space in question, providing valuable information for the reader's knowledge and for the preservation of its geodiversity and sustainable management of the region.

Keywords: mapping; environmental planning, semiarid.

GJHSS-B Classification: FOR Code: 0406



MAPPING AND CHARACTERIZATION OF PHYSICAL NATURAL UNITS IN THE MUNICIPALITY OF MASSAPÊ, CEARÁ, BRAZIL

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Mapping and Characterization of Physical-Natural Units in the Municipality of Massapê - Ceará, Brazil

Mapeamento e Caracterização das Unidades Físico-Naturais do Município de Massapê - Ceará, Brasil

Mapecto y Caracterización de Unidades Físico-Naturales en el Municipio de Massapê - Ceará, Brasil

Vanessa Campos Alves ^α, José Falcão Sobrinho ^σ, Simone Ferreira Diniz ^ρ, Bruna Lima Carvalho ^ω,
Rejane Maria Lima de Sousa [¥] & Nayane Fernandes [§]

Resumo- A pesquisa "Mapeamento e Caracterização das Unidades Físico-Naturais do Município de Massapê, Ceará" tem como objetivo lançar luz sobre a riqueza geográfica e ambiental da região sertaneja do nordeste brasileiro, explorando a complexidade do sertão nordestino. Dessa forma abrange o mapeamento de unidades físico-naturais do município de Massapê, no estado do Ceará, considerando sua importância para o planejamento territorial e a gestão ambiental, a caracterização da natureza do município permite a compreensão das dinâmicas e interações entre o ambiente e as atividades humanas, fornecendo dados relevantes para estratégias de preservação e desenvolvimento sustentável. Conclui-se que a pesquisa contribui significativamente para o entendimento integrado do espaço geográfico em questão, fornecendo informações valiosas para conhecimento do leitor e para a preservação de sua geodiversidade e gestão sustentável da região.

Palavras-chave: mapeamento; planejamento ambiental, semiárido.

Abstract- The research "Mapping and Characterization of the Physical-Natural Units of the Municipality of Massapê, Ceará" aims to shed light on the geographical and environmental richness of the backcountry region of northeastern Brazil, exploring the complexity of the northeastern hinterland. In this way, it covers the mapping of physical-natural units in the municipality of Massapê, in the state of Ceará, considering its importance for territorial planning and environmental management, the characterization of the nature of the municipality allows the understanding of the dynamics and interactions between the environment and the human activities, providing relevant data for preservation and sustainable development strategies. It is concluded that the research contributes significantly to the integrated understanding of the geographic space in question, providing valuable information for the reader's knowledge and for the preservation of its geodiversity and sustainable management of the region.

Keywords: mapping; environmental planning, semiarid.

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Resumen- La investigación "Mapecto y Caracterización de las Unidades Físico-Naturales del Municipio de Massapê, Ceará" tiene como objetivo arrojar luz sobre la riqueza geográfica y ambiental de la región interior del noreste de Brasil, explorando la complejidad del interior del noreste. De esta manera, abarca el mapecto de unidades físico-naturales en el municipio de Massapê, en el estado de Ceará, considerando su importancia para la planificación territorial y la gestión ambiental, la caracterización de la naturaleza del municipio permite comprender la dinámica y interacciones entre el medio ambiente y las actividades humanas, proporcionando datos relevantes para estrategias de preservación y desarrollo sostenible. Se concluye que la investigación contribuye significativamente a la comprensión integrada del espacio geográfico en cuestión, brindando información valiosa para el conocimiento del lector y para la preservación de su geodiversidad y el manejo sustentable de la región.

Palabras clave: mapecto; planificación ambiental, semiárido.

1. INTRODUÇÃO

A presente pesquisa, intitulada "Mapeamento e caracterização das unidades físico-naturais do município de Massapê, Ceará", busca lançar luz sobre a riqueza geográfica e ambiental deste município imerso na superfície sertaneja do nordeste brasileiro. A complexidade do sertão nordestino, marcado por características únicas e desafiadoras, revela-se como um ambiente de resiliência e adaptabilidade.

Por meio do mapeamento das unidades físico-naturais, torna-se possível a representação gráfica e espacial das características e distribuição de elementos como por exemplo, as formações rochosas, a cobertura vegetal, a hidrografia, os solos e entre outros. Esses elementos presentes no município, se denominam unidades físico-naturais, estudá-las nesse contexto permite que se compreenda suas dinâmicas e interação entre o ambiente e as atividades humanas que por sua vez são complexas e variam de acordo com o contexto espacial e temporal no qual se inserem.

Isso ocorre devido a notável capacidade humana em causar impactos significativos no ambiente em um período de tempo mais curto do que aquele necessário para a dinâmica evolutiva de reconstituição da natureza. Sendo portanto, um procedimento técnico de grande relevância para o planejamento territorial e a gestão ambiental, por proporcionar dados sobre o ambiente que possibilitam por exemplo, a localização ou delimitação de zonas específicas para diferentes usos, áreas urbanas, rurais, áreas de preservação, de risco ou de ecossistemas frágeis, o conteúdo que se obtém de um mapeamento assertivo contribui diretamente para a elaboração de estratégias eficazes de preservação e conservação dos recursos naturais, bem como na prevenção de impactos ambientais negativos por meio da implementação de medidas alinhadas a um desenvolvimento territorial ordenado e sustentável.

II. CARACTERIZAÇÃO DA ÁREA DE ESTUDO

O município de Massapê está localizado na porção Noroeste do estado do Ceará com latitude 3° 31' 22" Sul e longitude: 40° 30' 24" Oeste. Seus limites municipais são ao norte Santana do Acaraú e Senador Sá, ao sul Meruoca e Sobral, a leste Santana do Acaraú e Sobral e oeste, Senador Sá, Moraújo, Alcântaras e Meruoca (IPECE, 2017). Quanto a regionalização, se insere na região de planejamento do Sertão de Sobral, na Mesorregião Noroeste cearense e Microrregião de Sobral de acordo com a divisão do IBGE (2017). É marcado por uma diversidade de características físico-naturais que se estendem entre a Superfície Sertaneja e as imponentes serras, revelando uma paisagem rica e repleta de complexidade.

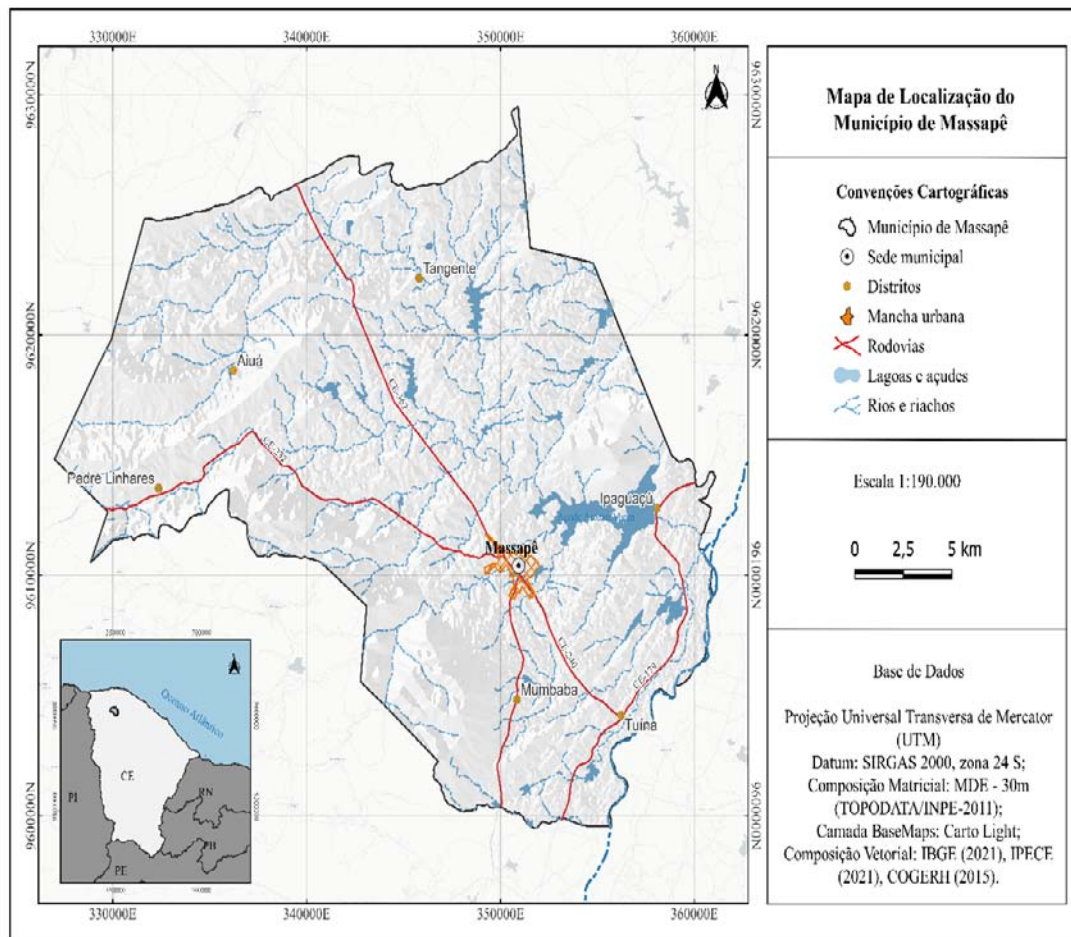
A presença predominante da Superfície Sertaneja na região reflete a ação secular dos processos exógenos. Este cenário é influenciado por um embasamento cristalino composto por rochas magmáticas e metamórficas, especialmente gnaisses, migmatitos diversos, xistos, quartzitos, granitos e metaplutônicas (CPRM, 1998). A compartimentação litológica diversa, desenvolvida em zonas de falhas herdadas da estruturação pré-cambriana, dá origem a uma morfologia única. A presença de sequências sedimentares, como conglomerados, arenitos, siltitos e folhelhos, intercaladas por rochas vulcânicas (CPRM, 1998), completa o mosaico litológico da Superfície Sertaneja.

Em contraste, as serras na área de estudo revelam-se como elementos geográficos imponentes, proporcionando uma elevação marcante na topografia. A dinâmica tectônica segundo (Santos et al 2008), associa-se à Orogênese Brasileira, com uma colisão tectônica Pan-Africana, desencadeou a evolução geológica dessas serras. Inseridas no domínio Médio Coreáú, NW da Província de Borborema, essas serras

são constituídas por uma variedade de rochas, desde granitos e gnaisses até migmatitos.

Fazem-se presente no município, algumas poções de serras secas e subúmidas, contribuindo para a variação do relevo local. Essas serras não apenas moldam a paisagem, mas também desempenham um papel crucial na distribuição das águas, influenciando padrões de dissecação e morfologias de relevo soerguidas.

A interação entre a superfície sertaneja e as serras possuem uma dinâmica onde os processos geológicos moldam a morfologia e as características físico-naturais da região. Essa integração é evidente nas diferentes tipologias de usos e cobertura da terra, que variam de forma significativa entre essas duas zonas geográficas distintas. Ao compreender essa caracterização da área de pesquisa, torna-se possível o entendimento sobre a geodiversidade local uma visão aprofundada de suas dinâmicas ecológicas.



Fonte: IBGE, (2021); IPECE, (2021); COGERH, (2015) Mapa organizado pelos autores

Mapa 1: Localização do município de Massapê, CE

III. PROCEDIMENTOS METODOLÓGICOS

Os procedimentos metodológicos adotados para esta pesquisa envolvem uma série de passos fundamentais para o alcance dos objetivos desta pesquisa sendo estes:

- 1) *Levantamento bibliográfico*: Inicialmente realizou-se um levantamento bibliográfico abrangente com intuito de reunir informações de diferentes pesquisas de temática semelhante ou de conteúdos relacionáveis realizadas sobre o município de Massapê, identificando o conhecimento já existente e algumas lacunas que oportunizam o avançar das pesquisas. Durante o levantamento bibliográfico, as informações sistematizadas foram coletadas considerando não apenas as características isoladas, mas também as conexões e influências mútuas entre os diferentes aspectos físicos e naturais.
- 2) *Coleta de dados geoespaciais*: Por meio de imagens de satélites para a identificação e delimitação preliminar das características físicas da área. A base matricial utilizada corresponde ao

- 3) *O processamento e análises dos dados*: Este passo foi realizado por meio de software de geoprocessamento e Sistemas de Informações Geográficas (SIG), permitiu uma análise integrada e a geração de mapas temáticos, revelando a distribuição espacial das características físico-naturais da área em estudo. É relevante destacar que as escalas atribuídas foram selecionadas com base na natureza multifacetada da área de estudo, reconhecendo a necessidade de abordar tanto elementos regionais quanto locais, foram produzidos mapas temáticos com diferentes escalas, notadamente as escalas de 1:190,000 e 1:140,000, oferecem vantagens específicas na

representação cartográfica, permitindo a ênfase em diferentes detalhes geográficos. A escala menor 1:190,000 proporciona uma visão mais ampla e abrangente da região, destacando padrões e relações regionais, enquanto a escala maior 1:140,000 enfatiza detalhes locais com maior precisão.

- 4) *Pesquisa de campo*: Realizou-se uma pesquisa de campo durante os meses de dezembro de 2022 (pré estação chuvosa) e janeiro e fevereiro de 2023 (início da estação chuvosa). A escolha destes períodos permitiu observar sobre as características do ambiente antes da intensificação das chuvas enquanto a continuação das pesquisas durante o período chuvoso evidenciou as transformações no ambiente em decorrência das condições de tempo mais úmidas. Esse passo incluiu observações, verificações e descrições das características da área identificadas por meio de sensoriamento remoto e dados cartográficos e mencionadas em referências bibliográficas. A coleta de informações sobre o relevo, vegetação, solos, usos da terra, recursos hídricos e outros aspectos relevantes foram precedidos de registros fotográficos, coletas de coordenadas e conversas informais com moradores e agricultores locais que possuíam maior afinidade com o ambiente natural e as atividades econômicas desenvolvidas em cada ponto de parada.

As observações e descrições da área foram guiadas a partir de um viés geossistêmico, enfocando não apenas características isoladas, mas também as relações entre elementos naturais e atividades humanas. Para isso, adotou-se uma abordagem integrada e interdisciplinar para o estudo das paisagens, considerando a interação complexa entre esses fatores. Essa perspectiva visa compreender as dinâmicas e processos que moldam as características geográficas de uma região, promovendo, assim, uma visão abrangente e holística do espaço geográfico em questão.

IV. RESULTADOS E DISCUSSÕES

a) *Geologia*

Uma colisão tectônica Pan-Africana ocorrida no bloco continental do Gondana designada de Orogênese Brasileira no Neoproterozóico desencadeou toda a evolução geológica do Brasil. E nesse contexto forma-se a plataforma Sul-Americana e mais tarde sendo esta dividida em províncias tectônicas, em específico, a província Borborema que compreende grande parte do Nordeste do Brasil, composto predominantemente por rochas pré-cambrianas, registra uma história evolutiva longa e complexa, que remontam três eventos tectonotermiais principais, que

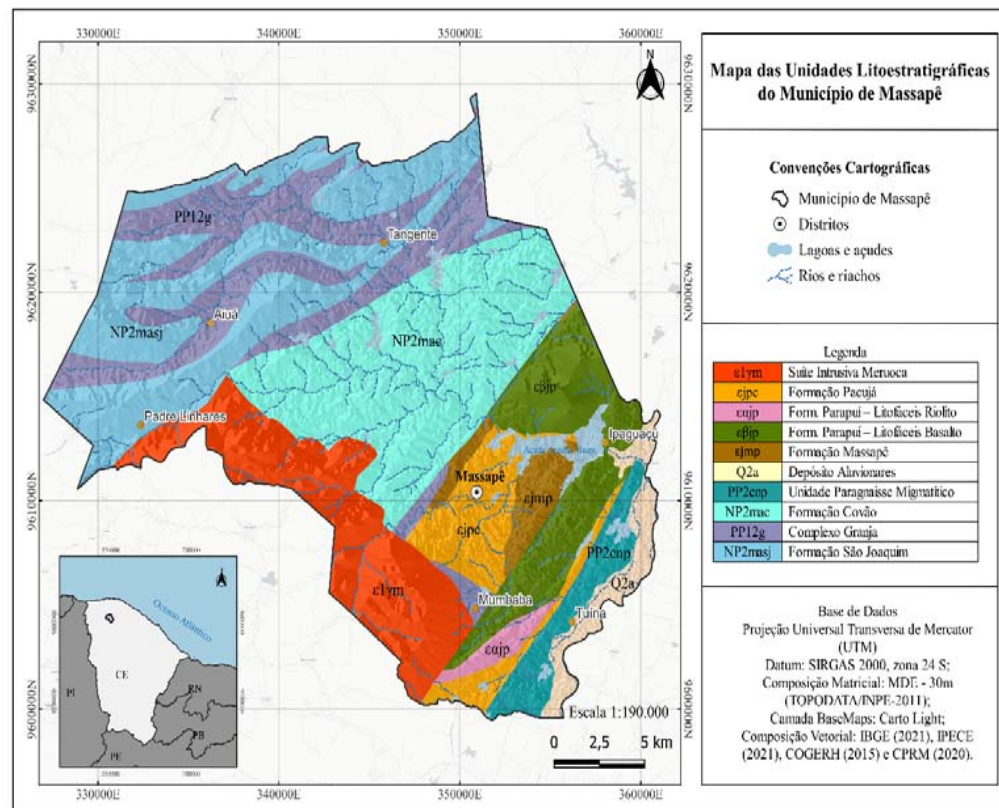
ocorreram no Arqueano, Paleo e Neoproterozóico (Mojzeszowicz, 2009).

Por essa dinâmica geológica o município de Massapê apresenta uma compartimentação litológica diversa representada sob um conjunto de morfologias desenvolvidas em zonas de falhas herdadas da estruturação pré-cambriana. Está inserido no domínio Médio Coreaú, NW da Província de Borborema e da Zona de Cizalhamento de Sobral-Pedro II compreendendo um cinturão colisional Brasileiro/Panafricano formado durante a aglutinação do Gondwana Ocidental (Santos et al 2008). Compõe-se de rochas do embasamento cristalino pré-cambriano, como gnaisses, migmatitos diversos, xistos e quartzitos, e rochas plutônicas e metaplutônicas de composição predominantemente granítica (CPRM, 1998). Sequências sedimentares de conglomerados, arenitos, siltitos e folhelhos, intercaladas por rochas vulcânicas (basaltos, andesitos e riolitos) de idade eopaleozóica. E coberturas aluvionares, quaternárias, formadas por areias, siltes, argilas e cascalhos (CPRM, 1998). Esse mosaico litológico está compartimentado pelos grupos Martinópole, Jaibaras (770 Ma), e complexo Granja (2.350 Mas). Além de uma porção do território inserido em áreas do complexo granítico da serra da Meruoca. Este último, também designado de Suíte Intrusiva Meruoca resulta dos pulsos magmáticos tardios, pós-orogênicos, do intenso magmatismo granítico ocorrido no evento Brasileiro na Província Borborema. (NASCIMENTO, 2012).

De acordo com Teixeira (2010):

"No Neoproterozóico ocorreu à deposição das sucessões sedimentares dos grupos Martinópole (Neves 1975) e Ubajara (Nascimento & Gava 1979 in Nascimento 2000). Posteriormente foram depositados os sedimentos que deram origem as rochas do Grupo Jaibaras (Costa et al 1979). Uma importante atividade vulcânica basáltica ocorreu ainda no Neoproterozóico, e constitui a Suíte Parapuí (Costa et al 1979, op. Cit), inserida no Gráben Jaibaras".

Constituída por rochas de natureza alcalina a peralcalinas de granulação grossa a fina, classificados como álcali-feldspato granitos e granitos quartzosieníticos. (SANTOS et al, 2008). Na compartimentação referente ao grupo Martinópole encontram-se sequências sedimentares neoproterozóicas, submetidas a vários graus de metamorfismo durante a orogenia Brasileiro. Com presença de corpos de metacalcários com intercalções subordinadas de metassedimentos siltico argilosos e arenosos (CPRM, 2006). Faz parte deste domínio as unidades de formação São Joaquim, Covão e o Complexo Granja este último composto por granitos, gnaiss-migmatitos e granulitos. (CPRM, 2006). E das rochas do Grupo Jaibaras encontram-se sequências sedimentares e vulcano sedimentares do eopaleozoico associadas a rifts, pouco deformadas e metamorizadas. (CPRM, 2006).



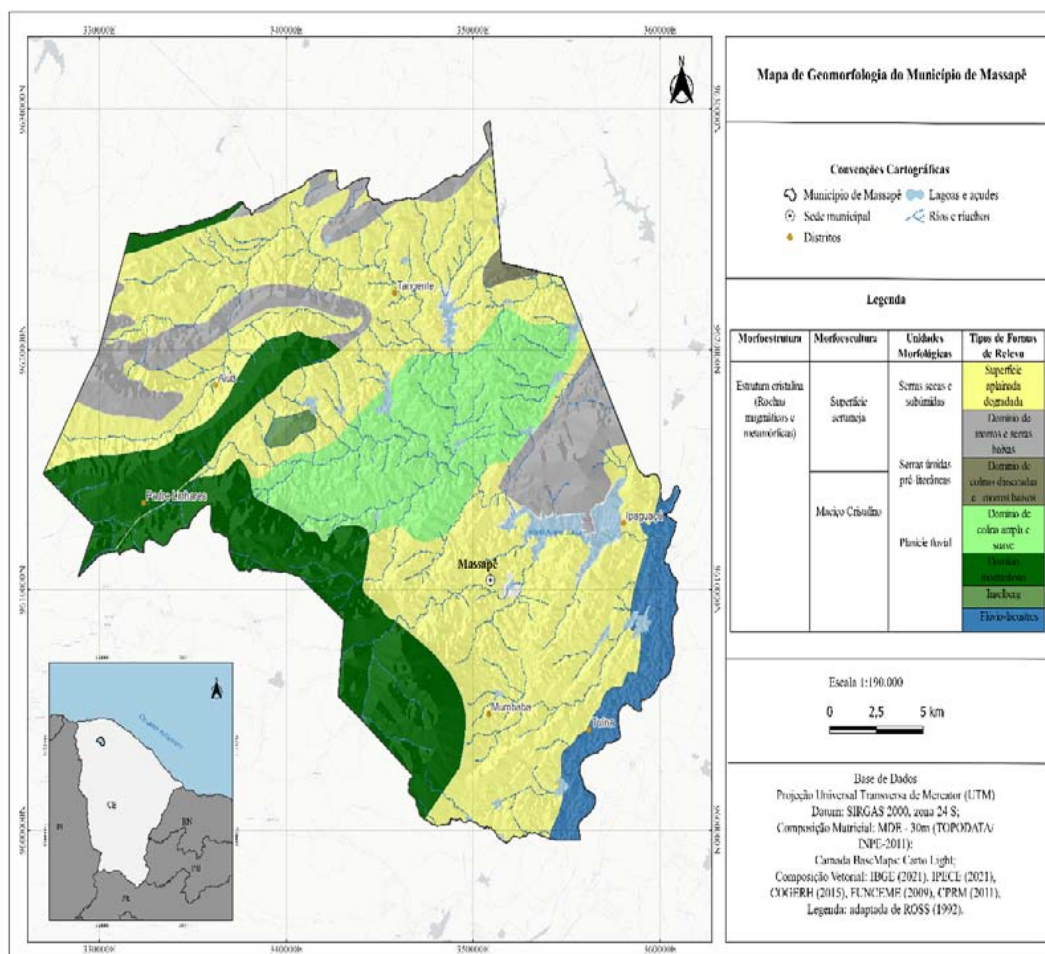
Fonte: IBGE, (2021); IPECE, (2021); COGERH, (2015) e CPRM, (2011). Mapa organizado pelos autores

Mapa 2: Compartimentação Geológica do Município de Massapê, CE

b) Geomorfologia

A morforestrutura da área possui embasamento cristalino (rochas magmáticas e metamórficas) e sua morfoescultura é a Superfície Sertaneja, resultante da ação dos processos exógenos ao longo do tempo.

Do ponto de vista do modelado, as unidades morfológicas apresentadas são: As serras secas e subúmidas, serras úmidas pré-litorâneas e planície fluvial. Os agrupamentos dos tipos de formas correspondem as superfícies aplainadas degradadas, domínio de morros e serras baixas, domínio de colinas dissecadas e morros baixos, domínio de colina ampla e suave, domínio montanhoso, Inselberg e planície flúvio-lacustre. A compartimentação geomorfológica predominante no município de Massapê é a superfície sertaneja (ALVES *et al.* 2023), esta compartimentação possui um material geológico do tipo cristalino, são superfícies embutidas entre níveis de planaltos sedimentares ou cristalinos, com altitudes abaixo de 400m, apresenta acentuada diversidade litológica, amplamente submetida às condições de semiaridez, com irregularidades pluviométricas no tempo e no espaço (SOUZA, 2006). Essas superfícies se inserem no cenário das grandes depressões interplanálticas.



Fonte: IBGE, (2021); IPECE, (2021); COGERH, (2015); FUNCERH, (2009); CPRM, (2011); Legenda adaptada de Ross, (1992). Mapa organizado pelos autores

Mapa 3: Geomorfologia do Município de Massapê

Nesse cenário, predominam solos rasos e pedregosos (Neossolos Litólicos), vegetação predominante de porte arbustivo além da mata ciliar do rio Ipaguaçu mirim. Trata-se de uma área que por estar situada no entorno do açude, predominam as atividades de criação, pescaria e pontos de lazer as margens do açude.

As feições de maior detalhamento geomorfológico inseridas dentro da compartimentação maior da superfície sertaneja na área de estudo são referentes aos tipos de formas de Superfície aplainada degradada, apresentando-se predominante na área de estudo, na porção norte e nordeste e na porção ao sul e sudeste do mapa 4. Essas amplas superfícies aplainadas configuram-se como as mais amplas do estado. O pediplano sertanejo se estende para o interior do estado até o sopé da Chapada do Araripe ao sul, a oeste se estende até a borda da bacia Sedimentar do Parnaíba, apresenta suave inclinação em direção à zona litorânea. Na área de estudo, a superfície sertaneja serve de pedestal para grandes relevos do Ceará, tal como o Maciço Cristalino da Meruoca.

Os relevos de aplainamentos, configuram-se como “Superfícies suavemente onduladas, com declividades entre 3% a 8%, essas superfícies são promovidas pelo arrasamento geral dos terrenos e posterior retomada erosiva proporcionada pela incisão suave de uma rede de drenagem incipiente”, (Brasil, 2010.p.14). Inserem-se, também, no contexto das grandes depressões interplanálticas do território brasileiro.

A área de estudo compreende a porção a barlavento no setor leste do Maciço Cristalino da Meruoca, considerado como serra úmida. “Representam um conjunto de maciços montanhosos sobrelevados em meio ao piso regional de cotas baixas, determinado pelas superfícies de aplainamento que compõem a Superfície Sertaneja” (BRASIL, 2014, p. 53).

As chamadas “serras secas” mapeadas na área de estudo, destaca-se a prevalência de processos de intemperismo físico e geração de solos pouco profundos ou rasos, arenosos ou cascalhentos (Cambissolos Háplicos e Neossolos Litólicos), com

ocorrência de muitos blocos rochosos nas vertentes íngremes dos maciços residuais, estando revestidos por mata atlântica subcaducifólia, floresta estacional decídua (caducifólia) ou por caatinga arbórea (PEREIRA; SILVA, 2005).

O domínio de morros e serras baixas caracteriza-se na continuação do domínio montanhoso do Maciço da Meruoca, a oeste, e nas proximidades do açude Ipaguaçu Mirim, esse domínio é conhecido popularmente como Serrrote do Madeiro.

Apresenta declividade de (8 à 75%) com relevos ondulados a escarpados. São relevos de degradação em litologia cristalina no caso da área de estudo. "Relevo de morros convexo-côncavos dissecados e topos arredondados ou aguçados. Também se insere nessa unidade o relevo de morros de topo tabular, característico das chapadas intensamente dissecadas e desfeitas em conjunto de morros de topo plano" (BRASIL, 2010, p.18). Apresenta sistema de drenagem principal com restritas planícies aluviais. Nesse domínio há predomínio de processos de morfogêneses conforme descrito:

Predomínio de processos de morfogênese (formação de solos pouco espessos em terrenos declivosos, em geral, com moderada a alta suscetibilidade à erosão). Atuação frequente de

processos de erosão laminar e linear acelerada (sulcos e ravinas) e ocorrência esporádica de processos de movimentos de massa. Geração de colúvios e, subordinadamente, depósitos de tálus nas baixas vertentes. Amplitude de relevo: 80 a 200m, podendo apresentar desnivelamentos de até 300m. Inclinação de vertentes: 15°-35°. (BRASIL, 2010, p. 18).

O Domínio de Colinas Dissecadas e de Morros baixos (figura 1), especificamente na área de estudo, são relevos de degradação em litologia cristalina. Apresentam vertentes convexo-côncavas e topos arredondados ou aguçados. Sistema de drenagem principal com deposição de planícies aluviais restritas ou em vales fechados. Equilíbrio entre processos de pedogênese e morfogênese (formação de solos espessos e bem drenados, em geral, com moderada suscetibilidade à erosão). Atuação frequente de processos de erosão laminar e ocorrência esporádica de processos de erosão linear acelerada (sulcos, ravinas e voçorocas). Geração de rampas de colúvios nas baixas vertentes (BRASIL, 2010, p.18).

Esse domínio é característico de declividades 20-75%, apresenta amplitude de relevo de 30 à 80m, com inclinação de vertentes de 5°-20°. Os solos presentes neste domínio são Neossolos Litólicos, rasos e pedregosos.



Fonte: Autores (2022)

Figura 1: Domínio de colinas dissecadas na localidade de baixo, Massapé

O Domínio de colinas amplas e suaves (figura 2), apresenta-se de forma bem expressiva na área de estudo, caracterizando a porção central do município. Possui declividade de 3 a 20%, predominando relevos suave ondulados. "Relevo de colinas pouco dissecadas, com vertentes convexas e topos amplos, de morfologia tabular ou alongada. Sistema de drenagem principal com deposição de planícies aluviais relativamente amplas" (BRASIL, 2010, p.16).



Fonte: Autores (2022)

Figura 2: Colinas amplas e suaves ao fundo, modeladas sobre o embasamento cristalino, situadas nas proximidades do açude da Cassimbinha

Domínio montanhoso (figura 2) corresponde aos setores do município de Massapê que se estende até o topo do maciço cristalino da Meruoca, perfazendo a porção a barlavento de Meruoca. Relevo montanhoso, muito acidentado. Apresenta vertentes predominantemente retilíneas a côncavas, escarpadas e topos de cristas alinhadas, aguçados ou levemente arredondados, com sedimentação de colúvios e depósitos de tálus. Sistema de drenagem principal com processos de entalhamento. Possui franco predomínio de processos de morfogênese (formação de solos rasos em terrenos muito acidentados, em geral, com alta suscetibilidade à erosão). Há atuação frequente de processos de erosão laminar e de movimentos de massa. Geração de depósitos de tálus e de colúvios nas baixas vertentes (BRASIL, 2010).

Esse domínio montanhoso, possui amplitude de relevo acima de 300 m, podendo apresentar, localmente, desnivelamentos inferiores a 200 m. Possui

inclinação das vertentes de 25°-45°, com ocorrência de paredões rochosos subverticais (60°-90°), (BRASIL, 2010). Esse domínio, geralmente, é gerado por processos de erosão diferencial estão sustentadas por rochas graníticas e quartzíticas, via de regra, mais resistentes ao intemperismo e à erosão, em relação ao embasamento cristalino circundante nas superfícies aplainadas. Comumente, possuem topos ou cimeiras colinosos (figura 3), constituem os chamados brejos de altitude. Neste contexto, destaca-se a prevalência de processos de intemperismo químico e geração de solos profundos areno-argilosos ou argilo-arenosos, bem drenados, revestidos por redutos de mata atlântica subperenifólia (BRASIL, 2014).

Em relação as atividades econômicas nesse domínio, se destaca práticas tradicionais de subsistência, como retirada da vegetação seguida de queimadas, em vertentes com alta declividade (figura 4).



Fonte: Autores (2022)

Figura 3: Relevo montanhoso com topos colinosos, comunidade de São Damião/Massapê.



Fonte: Autores (2022)

Figura 4: Relevo montanhoso com presença de práticas tradicionais de queimadas em vertentes declivosas.

O domínio de Inselbergs, constituem relevos residuais destacados na paisagem aplainada, remanescentes do arrasamento geral dos terrenos. Possui amplitude de relevo: 50 a 500 m. Inclinação das vertentes: 25°- 45°, com ocorrência de paredões rochosos subverticais (60°-90°), (BRASIL, 2010). Essas formas de relevos são constituídas, invariavelmente, por rochas mais resistentes aos agentes externos, a exemplo do Inselbergue presente na localidade de Cachoeirinha.

O padrão agradacional em planície flúvio-lacustre encontra-se presente na área de estudo

perfazendo toda a porção sudeste do município, situada entre as comunidades de Lagoa grande e Tapera baixa. A planície flúvio-lacustre pertence ao domínio das unidades agradacionais, na área de estudo é caracterizada pelo rio Acaraú, onde há o espraiamento da drenagem (figura 5). Geralmente nesses ambientes há presença de atividades econômicas como pesca, plantação de pasto, criação de animais entre outras.



Fonte: Autores (2022)

Figura 5: Planície flúvio-lacustre situada na comunidade de Lagoa Grande-Massapê.

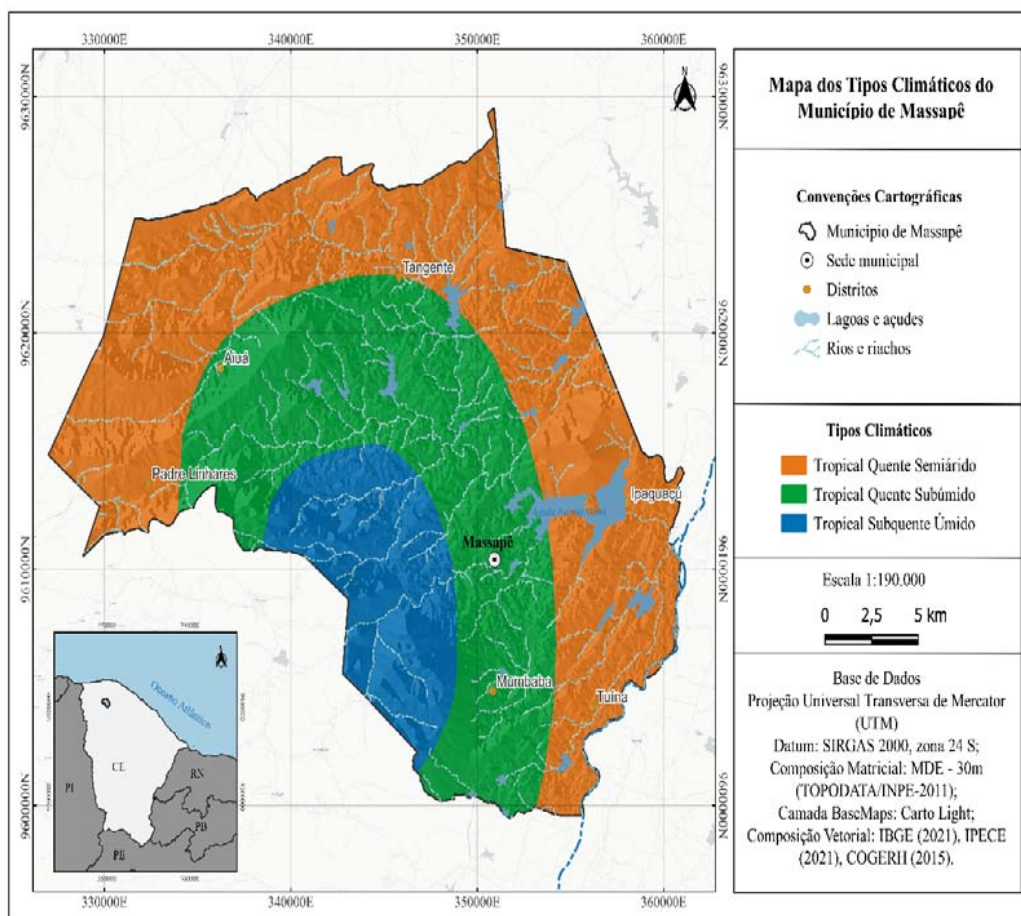
As planícies fluviais ou flúvio-lacustres, são definidas de acordo com a classificação da CPRM (2010), como Superfícies sub-horizontais, constituídas de depósitos arenoargilosos a argiloarenosos, apresentando gradientes extremamente suaves e convergentes em direção aos cursos d'água principais. Terrenos imperfeitamente drenados nas planícies de

inundação, sendo periodicamente inundáveis; bem drenados nos terraços. Os abaciamentos (ou suaves depressões em solos arenosos) em áreas planas ou em baixos interflúvios, denominados Áreas de Acumulação Inundáveis. A amplitude de relevo é zero, possuindo inclinação de vertentes: 0°-3°, (BRASIL, 2010).

c) Características Hidroclimáticas

O município de Massapê está situado na Zona Fisiográfica Centro-Norte do Ceará. A maior parte do seu território estende-se no sertão e a parte restante abrange as encostas orientais da Serra da Meruoca. (AGUIAR, 1968, p. 31). Tal configuração territorial confere ao município três distintas zonas climáticas designadas pela classificação de Köppen como: Clima Tropical Quente Semi-Árido / Clima Tropical Quente Subúmido e Clima Tropical Subquente Subúmido conforme ilustrado no mapa abaixo. Registrando que predomina em maior parte de seu território o clima semiárido, e sensações térmicas amenizas em porções de maior elevação topográfica da serra da Meruoca, "A oscilação da disponibilidade hídrica no semiárido brasileiro, torna a vegetação da caatinga extremamente dinâmica e sazonal, onde em períodos secos a vegetação perde quase completamente suas folhas, enquanto em períodos úmidos a vegetação apresenta aspecto verdejante" (SILVA; CRUZ, 2018). "As características climáticas de uma região são essenciais na delimitação de ocorrências das espécies vegetais e

animais; contribuem para o desenho do relevo; atuam em processos erosivos; e desempenham importante papel na disponibilidade e no manejo dos recursos hídricos" (Silva, E.R.F; Araújo, R.L, 2018). Apresenta variação de temperaturas com valores médios entre mínimas de 26° e máximas de 28° e pluviosidade média de 749,5 mm (FUNCEME/IPECE, 2017). Podendo ultrapassar a 1.000 mm/ano conforme indicam os dados da Fundação Cearense de Meteorologia e Recursos Hídricos - FUNCEME, os níveis normais de precipitação para o município de Massapê são de 1129.7 mm/ano. O período de chuvas ocorre nos meses de janeiro a maio com uma pré-estação chuvosa no mês de dezembro. Numa série de 30 anos de precipitação analisadas a partir dos dados coletados no portal da FUNCEME, onde se encontram definidos como parâmetros os valores: de 0 a 684.9 mm (abaixo da média); de 684.9 mm a 940.7 mm (em torno da média) e acima de 940.7 mm (acima da média). Estabeleceu-se as seguintes situações conforme ilustradas no gráfico e mais detalhadamente na tabela.



Fonte: IBGE, (2021); IPECE, (2021) E COGERH, (2015). Mapa organizado pelos autores (2022)

Mapa 6: Tipos de climáticos

Tabela 1: Detalhamento do gráfico e classificação dos períodos chuvosos

Anos	Total de chuvas (mm)	Classificação dos períodos chuvosos	Anos	Total de chuvas (mm)	Classificação dos períodos chuvosos
1993	464	Abaixo da média	2008	1.099,8	Acima da média
1994	1308,5	Acima da média	2009	1.337,6	Acima da média
1995	958,2	Acima da média	2010	604	Abaixo da média
1996	1.124,6	Acima da média	2011	1.346,7	Acima da média
1997	615,6	Abaixo da média	2012	332,4	Abaixo da média
1998	476,7	Abaixo da média	2013	874,3	Em torno da média
1999	1.024,6	Acima da média	2014	353,7	Abaixo da média
2000	1.047,9	Acima da média	2015	460,2	Abaixo da média
2001	583,1	Abaixo da média	2016	719,7	Em torno da média
2002	773,9	Em torno da média	2017	1.140,1	Acima da média
2003	1.001,3	Acima da média	2018	873,7	Em torno da média
2004	904,5	Em torno da média	2019	1.096,4	Acima da média
2005	739,5	Em torno da média	2020	1.083,6	Acima da média
2006	1.041,6	Acima da média	2021	806,5	Em torno da média
2007	838,2	Em torno da média	2022	952,6	Acima da média

Fonte: Dados da funceme; tabela organizada pelos autores (2022)

A partir do período analisado de acordo com Marengo et al (2011), No Brasil, o fenômeno El Niño (1997/1998) provocou grande seca no semiárido do Nordeste, em 1998, talvez o mais intenso nos últimos 150 anos, estava associado a alta na taxa de crescimento da anomalia de TSM. Já no ano de 2009 os excessos de chuva e a ocorrência de enchentes afetaram a maior parte dos estados do Nordeste, particularmente entre abril e maio, influenciando no aumento das vazões e no volume armazenado dos reservatórios que abastecem as cidades. As altas temperaturas, insolação no ambiente e velocidade dos ventos influenciam drasticamente no balanço hídrico dos reservatórios do município, assim como a ocupação e uso das áreas no entorno e ao longo destes recursos impactam na qualidade da água.

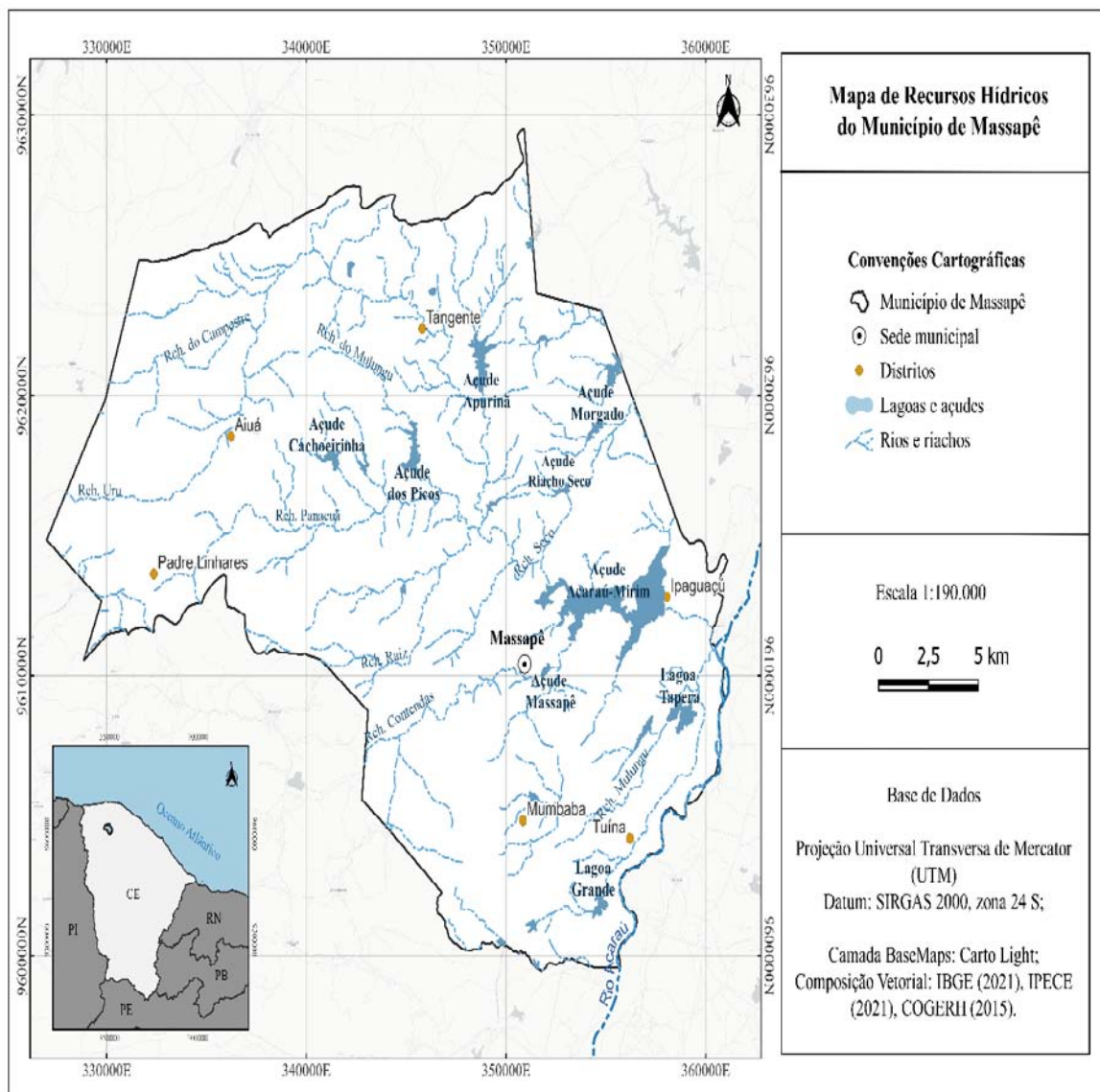
Com base nesse levantamento, contata-se que a situação de regime chuvoso de Massapê em torno da média histórica do estado do Ceará, indica uma certa estabilidade no regime das chuvas conforme especificados na tabela. O que não significa que o regime pluviométrico em torno da média se manteve uniforme ao longo dos anos, ocorrendo variações dentro dessa série de 30 anos, na qual registrou-se tanto períodos de baixa pluviosidade indicando períodos de estiagem refletindo na disponibilidade e qualidade de água dos reservatórios e impactando no abastecimento da população assim como na agricultura o que levou à adoção de medidas de enfrentamento da crise hídrica, na zona rural essas medidas se dão por meio de plantios mais resistentes a seca ou uso das tecnologias de convivência com o semiárido sendo estas o uso de cisternas de 1º e 2º água, poços, plantio em sistemas de quintais produtivos, plantios em mandalas ou PAIS (Produção Argoecológica Integradae Sustentável), entre outras demonstradas nas imagens que seguem na figura 6.



Fonte: Autora (2022 e 2023)

Figura 6: Mosaico de tecnologias de convivência com o Semiárido e técnicas agroecológicas em Massapê. a – cisterna; b – poço profundo; c – biodigestor; d – tanque de minhocário; e – tanque de armazenamento e redistribuição de águas cinzas; f – tanque de criação de paixes; g – quintal produtivo com agricultura orgânica; h – sistema de irrigação automático.

Em relação aos recursos hídricos implantados no município encontra-se diversos reservatórios que auxiliam no abastecimento da população conforme exposto no mapa 7 abaixo:



Fonte: IBGE, (2021); IPECE, (2021) E COGERH, (2015). Mapa organizado pelos autores, (2023)

Mapa 7: Recursos hídricos

d) Solos

As características pedológicas caracterizam-se como um elemento indispensável na compreensão do quadro paisagístico. Correlacionar os condicionantes das formas atuais do relevo com os solos e aspectos fitogeográficos é uma ferramenta relevante na compreensão integrada da área de estudo.

Conforme ressaltam Pereira e Silva (2005), os solos podem ser considerados como unidades naturais que dão sustentação às plantas, providos de propriedades e características particulares, cuja origem e evolução resultam, num determinado lugar, da ação conjunta do clima, organismos vivos, material de origem, relevo e tempo, os quais se constituem nos chamados fatores de formação.

No município de Massapê encontram-se os seguintes tipos de solos: Argissolo Vermelho-Amarelo Eutrófico; Argissolo Vermelho Eutrófico; Neossolo Litólico Eutrófico; Neossolo Flúvico Ta Eutrófico e Luvisolo Crômico Órtico. Indicados no mapa 8 abaixo:

As características de semiaridez têm reflexo nos processos de pedogênese constituindo baixa espessura dos Neossolos Litólicos, os quais compõem em maior abrangência a área de estudo. De acordo com o SiBCS (2018), solos com contato lítico ou lítico fragmentário dentro de 50 cm a partir da superfície, apresentando horizonte A ou hístico assente diretamente sobre a rocha ou sobre um horizonte C ou Cr ou sobre material com 90% (por volume) ou mais de sua massa constituída por fragmentos grosseiros (por

exemplo, cascalheira de quartzo) com diâmetro maior que 2 mm (cascalhos, calhaus e matacões). A figura 7, mostra o típico Neossolo Litólico, revestido da vegetação de caatinga.

Nos limites da escarpa e topo do Maciço da Meruoca é possível observar a ocorrência de Argissolo Vermelho (figura 8), coincidindo com as áreas com maiores altitudes, predomínio do intemperismo químico, proporcionando a ocorrência de solos com profundidade variável.

Quanto à classe de Argissolos Vermelhos-Amarelos, os quais ocorrem na porção setentrional da área, Diniz (2010), destaca que são solos minerais não hidromórficos, com horizonte A ou E contíguos ao B

textural não plântico, argila de alta ou baixa atividade e teores de ferro inferiores a 11%. Como a própria autora mencionou, a principal característica morfológica dos Argissolos é a presença de um horizonte B textural abaixo de um Horizonte A ou E.

Referente aos fatores de uso dessa classe de solo, Falcão Sobrinho (2007; 2009; 2020), destaca que na serra da Meruoca o processo erosivo se torna mais brusco, já que a mesma apresenta declividades acentuadas. Evidencia-se aí o manejo inadequado do solo, principalmente nas práticas agrícolas, acarretando problemas ligados aos elementos naturais, que trazem reflexos para própria sociedade (figura 9).



Fonte: Autores (2022)

Figura 7: Neossolo Litólico situado na superfície sertaneja de Massapê



Fonte: Autores (2022)

Figura 8: Classe de Argissolos Vermelho na serra da Meruoca. Figura 12 – Classe de Argissolos Vermelho-Amarelo



Fonte: Autores (2022)

Figura 9: Práticas de queimadas na classe de argissolos vermelho, localidade de Sítio Socorro

A classe de Luvissolos Crômicos encontra-se na porção sul da área com pouca abrangência. De acordo com a SiBCS (2018), são solos constituídos por material mineral, apresentando horizonte B textural com argila de atividade alta e saturação por bases alta na maior parte dos primeiros 100 cm do horizonte B (inclusive BA), imediatamente abaixo de qualquer tipo de horizonte A (exceto A chernozêmico).

Os Neossolos Flúvicos Eutróficos (figura 10), situados em áreas baixas seguindo a calha dos cursos fluviais, os quais são derivados de sedimentos aluviais com horizonte A assente sobre horizonte C constituído de camadas estratificadas. São solos jovens revestidos

de vegetação de várzea, em decorrência da sua proximidade das margens dos rios são fortemente influenciados pelas inundações e pelos processos naturais de assoreamento.

Dentre as características desse tipo de solo está na alta fertilidade natural, destinado para o uso agrícola, é muito usado para a prática de sistemas de irrigação (PEREIRA; SILVA 2005). Segundo a classificação do SiBCS (2018), são solos com argila de atividade baixa e saturação por bases $\geq 50\%$, ambas na maior parte do horizonte ou camada C (inclusive CA) dentro de 150 cm a partir da superfície do solo.



Fonte: Autores (2022)

Figura 10: Neossolo flúvico associado a vegetação de várzea

e) Vegetação

A vegetação em geral da área de estudo corresponde ao bioma Caatinga, lar das espécies que

se desenvolvem adaptadas as condições de semiáridade, suas fitofisionomias vegetais variam conforme influência de fatores como o clima local, a

presença de rios, as condições do solo e o impacto humano, como desmatamento e o uso da terra. Assim encontram-se espécies de porte arbóreo, abustivo, herbáceo, além de cactáceas e bromeliáceas, se estendendo sobre a área conforme levantamento da (CPRM, 1998; FUNCME, 2018) uma cobertura vegetal predominante de caatinga arbustiva aberta, vegetação de floresta subcaducifolia tropical pluvial (mata seca) e floresta subperenifolia tropical pluvio-nebular (mata úmida). Nas expedições de campo ao longo do município, observou-se as características ambientais de determinadas áreas relacionadas às referidas classificações de cobertura vegetal, descrevendo-se do seguinte modo:

f) *Caatinga Arbustiva Aberta*

Relacionada a área de superfície sertaneja. Tais composições foram observadas nos pontos sede – Tangente – Cassimbinha – Trapiá – Morgado e localidades próximas a cada ponto. Nestas áreas as espécies vão se adaptando às condições mais áridas perdendo suas folhagens e tomando um aspecto espinhoso e ressecado nos períodos de estiagem, sendo assim, reveste o ambiente uma vegetação composta principalmente por arbustos e árvores espinhosas, como Jurema (*Mimosa tenuiflora*) presente por toda a extensão do sertão, muitas árvores de Pereiro (*Aspidosperma pyrifolium* Mart) outras de Juazeiro (*Ziziphus joazeiro*), Oiticica (*Licania rigida*), Caatingueira (*Poincianella pyramidalis*), Sabiá (*Mimosa caesalpiniaefolia*), Angico (*Anadenanthera colubrina*), Pau d'arco (*Tabebuia serratifolia*), Umbuzeiro (*Spondias tuberosa*), Marmeleiro (*Croton sonderianus*), Carnaúbas delineando cursos d'água e cactáceas, como o mandacaru (*Cereus jamacaru*), o xique-xique (*Pilosocereus polygonus*) e o facheiro (*Pilosocereus pachycladus*).

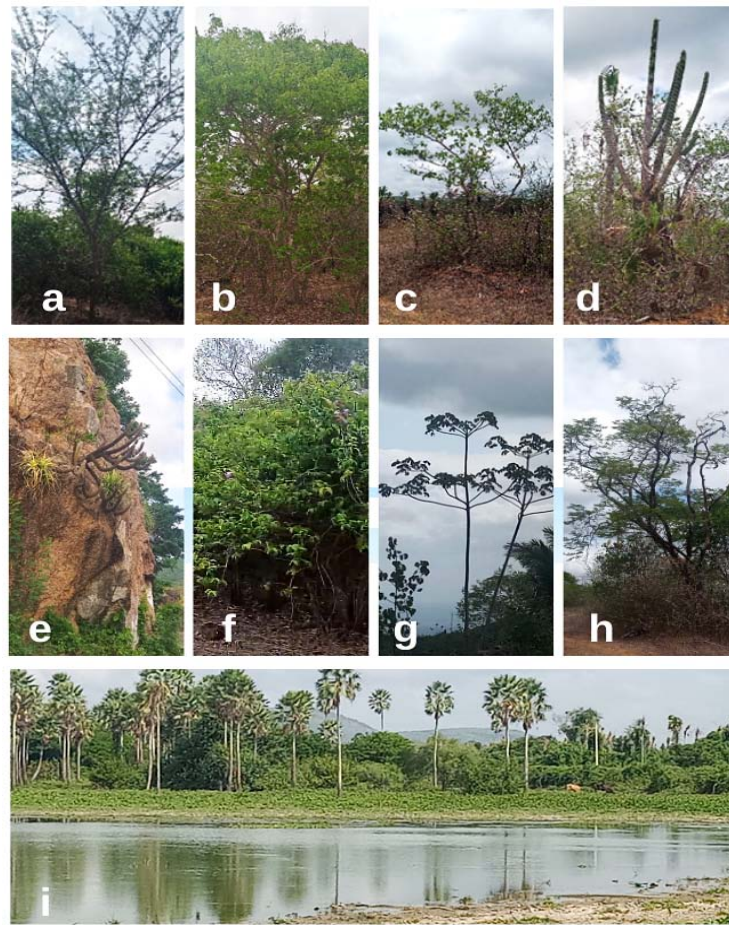
Com algumas semelhanças, ainda na superfície sertaneja, as fitofisionomias correspondentes as áreas de acumulação do rio Acaraú caracterizam-se por um extrato arbóreo-arbustivo, marcado por grande quantidade de abustos de Marmeleiro (*Croton sonderianus*), Mufumbo (*Combretum leprosum*), Jucá (*Caesalpinia ferrea*), Juazeiro (*Ziziphus joazeiro*), Mamona (*Ricinus communis*), Viúva alegre (*Cryptostegia grandiflora*), Umbuzeiro (*Spondias tuberosa*) com predomínio de Carnaúbas (*Copernicia prunifera*).

A mata ciliar encontrada no entorno dos corpos hídricos ou nos cursos d'água que correm pelo município, apresenta-se em alguns pontos parcialmente ou totalmente removidas para o plantio de frutíferas, além dessas vegetações encontram-se inúmeras espécies herbáceas e rasteiras como o Mussambê (*Tarenaya spinosa*), a Salsa-do-rio (*Ipomoea asarifolia*), e diversas gramíneas associadas as áreas alagáveis. Essa composição, possui maior adaptação aos solos

aluviais, que são ricos em nutrientes e inundados periodicamente, se repentido também na área de deposição do rio contendas, um dos principais cursos d'água que percorre a cidade no sentido Oeste-Leste a partir de sua origem na serra da Meruoca até o ponto onde deságua no açude Acaraú Mirim, trata-se de um ecossistema bastante degradado em decorrência do uso indevido de seus recursos a exemplo dos despejos de esgotos residenciais, dos resíduos sólidos, a extração de areia e argila na área de preservação e a retirada da mata ciliar de seu leito agravando o equilíbrio e sua função ecológica.

Ainda na Superfície Sertaneja, no distrito de Mumbaba, constata a ocorrência continuada da caatinga arbustiva, também com sinais de degradação como extração vegetal e queimadas conforme mostra as imagens.

Ao lançar o olhar desse ponto em direção a serra da Meruoca que se ergue ao lado, torna-se possível avistar uma mundaça de vegetação que se estende entre esses dois pontos e avançando através dos sopés e vertentes do Maciço composições vegetais de Floresta subcaducifolia tropical pluvial (mata seca). (ver figura 11)



Fonte: Autores (2022)

Figura 11: Mosaico com algumas espécies de vegetação encontradas em Massapê: a – Jurema; b – Pereira; c- Mufumbo; d – Xique-Xique; e – Bromélias e Cactos; f – Arbustos de Viúva alegre; g – Torém; h – Pau de cheiro; i – Carnaúbas em torno do açude da localidade de Lagoa grande, vegetado por vegetação rasteira de salssa do rio e ao fundo arbustos de Caatingueira, Mameleiro, Mufumbo e Jurema.

g) Floresta subcaducifolia tropical pluvial (mata seca)

Seguindo em direção a Serra da Meruoca, num trajeto que partiu da sede Municipal às respectivas localidades de Contendas – Pé de Serra – Riacho Fundo – Sítio Socorro – São Damião e Santo Amaro, a fitofisionomia das vegetações da caatinga arbustiva, vão ganhando composições e estrutura de Floresta subcaducifolia tropical pluvial (mata seca) caracterizadas por uma densidade arbórea mais significativa. Ambos os ecossistemas compartilham adaptações semelhantes às condições semiáridas do ambiente, incluindo a perda de suas folhas durante a estação seca para minimizar a evapotranspiração. Constatou-se ao passar por esses pontos espécies de Jurema (*Mimosa tenuiflora*), Aroeira, Sabiá, Mororó, Mameleiro (*Croton sonderianus*), Jucá (*Caesalpinia ferrea*), Oiticica (*Licania rigida*), Bordão, Mufumbo, Torém, Palmeiras de coco babaçu, Jatobá, Palma, muitas Caranúbas, e frutíferas diversas como Ata, Mangueira, Cajueiro, Cajá, Acerola, entre outras. Conforme a expedição a campo avança em direção as

maiores altitudes como no caso das localidades de São Damião, Sítio Socorro, Meruquinha e Terra nova, as condições do ambiente começam a mudar, com temperaturas mais amenas e até um aumento na disponibilidade de água. Trata-se de zonas de transição ou intermediárias nas quais se percebe uma mistura de espécies de florestas subcaducifolia e subperenifolia. (figura 12).



Fonte: Autores (2022)

Figura 12: Transição de mata seca à mata úmida vista apartir do caminho para o Sítio Socorro, iniciando a área de preservação

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h) Floresta subperenifolia tropical plúvio-nebular (mata úmida)

Encontradas em superfícies de brejos de cimeira. Conforme explicado por (LIMA; MACÊDO; BASTOS, 2014) a cobertura vegetal da serra da Meruoca apresenta aspectos diferenciados em razão da cota altimétrica do relevo e da presença de umidade. Em outras palavras, a ocorrência de chuvas

orográficas e a precipitação em orvalho determinado pelo nevoeiro em níveis mais elevados de altitude (FALCÃO SOBRINHO, 2020) condicionam características de ambiente úmido predominando vegetações de extrato arbóreo e resquícios de Mata Atlântica em contraste com áreas que demonstram uma vegetação descaracterizada dessas condições. (Figura 13)



Fonte: Autores (2022)

Figura 13: Ambiente úmido na localidade de São Damião na serra da Meruoca

Com a estação seca menos acentuada nesses ambientes, as espécies arbóreas de folhas perenes são predominantes. As pesquisas existentes realizadas na Caatinga constataam que atividades antrópicas têm conduzido a vegetação a sucessão secundária em áreas que já passaram por modificações (Lima; Macêdo; Bastos, 2014), proveniente “dos desmatamentos realizados sem qualquer critério conservacionista”. (SOUZA; OLIVEIRA, 2006).

Nas áreas mais degradadas, é possível observar concentrações de espécies predominantes das sucessões secundárias, tais como palmeiras de coco babaçu no topo e nas encostas, a presença da

jurema (*Mimosa tenuiflora* (Willd.) Poir) característica das regiões de superfície sertaneja, além de mulungu (*Erythrina velutina* Jacq.), sabiá (*Mimosa caesalpinifolia* Benth.), angico (*Anadenanthera macrocarpa* (Benth.) Brenan) e marmeleiro (*Cronquistianthus sonderianus*).

Na região em geral, são desenvolvidas atividades agrícolas tradicionais de subsistência, como o cultivo de milho, feijão, mandioca e diversas hortaliças, assim como uma variedade de frutas, incluindo banana, ata, manga, seriguela e caju, entre outras. Dentre essas, o caju é mais abundante e predomina por uma poção da área que recebe o nome popular de Serra do Cajueiro, onde a principal atividade

está relacionada à extração e comercialização da castanha de caju.

Devido a uma combinação de fatores climáticos e hídricos favoráveis, originados de nascentes ou cursos d'água na Serra da Meruoca,

certas áreas tornam-se propícias a formação de ambientes aquáticos utilizados para atividades recreativas e balneários onde a população pode desfrutar de momentos de lazer em contato com a natureza.



Fonte: Autores, (2022)

Figura 21: Balneário em ambiente úmido na localidade de Riacho Fundo na Serra da Meruoca

i) Usos e cobertura da terra

A análise dos usos e cobertura da terra é um relevante meio de se compreender o impacto das atividades humanas sobre o meio ambiente. De acordo com Santos; Nascimento / (2017 p.5454) "A reprodução das atividades econômicas sobre o substrato biofísico dos sistemas ambientais é influenciada por múltiplos interesses e complexas relações de apropriação dos recursos naturais disponíveis". Tecnologias como sensoriamento remoto por satélites e sistemas de informação geográfica (SIG) são frequentemente utilizadas para mapear e analisar essas tipologias de forma eficiente, isso permite identificar as mudanças ao longo do tempo, avaliar a expansão urbana, monitorar o desmatamento, áreas de importância ambiental, e entre outras questões.

No município de Massapê, da diversidade de tipologias representadas no mapa 8 encontram-se: 1) Formação Florestal; 2) Formação Savânica; 3) Formação Campestre; 4) Pastagem; 5) Mosaico de usos; 6) Área urbanizada; 7) Outras áreas não vegetadas; 8) Rios e lagos e 9) Outras lavouras perenes.

Segundo a classificação e descrição dos usos e coberturas da terra contidas no Manual técnico de uso da terra, IBGE (1999 p.58) e indicadas no mapa, tem-se:

Formação Florestal: Áreas com tipos de vegetação de dossel contínuo - Savana-Estépica Florestada, Floresta Estacional Semi-Decidual e Decidual, seu

monitoramento é vital para a manutenção da biodiversidade e o equilíbrio dos ecossistemas.

Formação Savânica: Apresenta vegetação com predomínio de espécies de dossel semi-contínuo - Savana-Estépica Arborizada, Savana Arborizada. Indica paisagens muitas vezes associada a práticas agrícolas.

Formação Campestre: Apresenta vegetação com predomínio de espécies herbáceas (Savana-Estépica Parque, Savana-Estépica Gramíneo-Lenhosa, Savana Parque, Savana Gramíneo-Lenhosa) + (Áreas inundáveis com uma rede de lagoas interligadas, localizadas ao longo dos cursos de água e em áreas de depressões que acumulam água, vegetação predominantemente herbácea a arbustiva). Constituem ambientes específicos que podem ser alvo de atividades agrícolas ou pastoris.

Pastagem: Áreas ocupadas com cultivos agrícolas de ciclo vegetativo longo (mais de um ano), que permitem colheitas sucessivas, sem necessidade de novo plantio. A expansão de áreas de pastagem está relacionada à atividades de pecuária, sendo importante entender a extensão dessas áreas para mitigar possíveis impactos ambientais, como a compactação do solo e a perda de biodiversidade.

Mosaico de Usos: Áreas de uso agropecuário onde não foi possível distinguir entre pastagem e agricultura. Podem apresentar múltiplos usos que demandam uma abordagem integrada.

Área Urbanizada: Áreas associadas a ambientes urbanos, que são espaços com grande concentração populacional e as atividades econômicas, sociais e culturais são diversificadas

Outras Áreas Não Vegetadas: Essas áreas podem incluir espaços industriais, zonas de mineração ou locais sujeitos a processos de degradação ambiental. O monitoramento é indispensável para evitar a degradação irreversível do solo.

Rios e Lagos: Áreas de ecossistemas aquáticos. A delimitação e monitoramento dos recursos hídricos é vital para uma gestão sustentável.

Outras Lavouras Perenes: Além das culturas comuns, a identificação de outras lavouras perenes pode apontar para práticas agrícolas diversificadas e estratégias de uso da terra.

V. CONCLUSÕES

No decorrer desta pesquisa sobre o município de Massapê, foram explorados aspectos da diversidade geográfica e ambiental. Na análise geológica mencionou-se sobre a influência da orogenia Brasileira na formação da região, destacando a compartimentação litológica diversa do município de Massapê. A geomorfologia apresentou uma variedade de paisagens, desde serras secas e subúmidas, passando pela superfície sertaneja e alcançando um uma pequena poção da planície fluvial do rio Acaraú, com destaque para a superfície sertaneja, revelando através do relevo a influencia direta nas atividades humanas e na ocupação da terra.

As características hidroclimáticas, com variações no regime pluviométrico ao longo dos anos, foram essenciais para entender a dinâmica da vegetação da caatinga e suas adaptações sazonais. A relação entre o clima semiárido predominante e as atividades econômicas locais, como a agricultura de subsistência, destaca a importância de estratégias de convivência com o Semiárido.

Com a análise pedológica mencionou-se a presença predominante de Neossolos Litólicos em resposta às condições de semiaridez. A correlação entre as características pedológicas e as formas de relevo contribuiu para uma compreensão mais abrangente da paisagem que se reveste de variadas espécies vegetacionais pertencentes ao bioma Caatinga caracterizado por sua adaptabilidade às condições climáticas semiáridas e resiliência das espécies da flora sertaneja, que são comumente impactadas pela sazonalidade das chuvas, e pelas atividades humanas ligadas ao uso ou degradação de suas espécies, evidenciando a interdependência entre a natureza e as comunidades locais.

Os usos e coberturas da terra, refletem como as comunidades locais interagem com o ambiente. A

agricultura de subsistência, notadamente adaptada às condições de semiaridez, destaca-se como uma prática resiliente. A ocupação urbana, por sua vez, apresenta desafios associados à infraestrutura e à gestão sustentável dos recursos naturais, e buscar meios de conservação da caatinga não apenas preserva a biodiversidade, mas também mantém os serviços ecossistêmicos essenciais para a qualidade de vida das populações locais.

Todo esse levantamento foi adicionado de mapas temáticos, tabelas, gráficos e registros fotográficos, dinamizando o teor dos dados e informações reunindo dessa forma informações multidisciplinares, permitindo ao leitor maior conhecimento e aproximação com a área de pesquisa.

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GLOBAL JOURNAL OF HUMAN-SOCIAL SCIENCE: B
GEOGRAPHY, GEO-SCIENCES, ENVIRONMENTAL SCIENCE & DISASTER
MANAGEMENT

Volume 24 Issue 1 Version 1.0 Year 2024

Type: Double Blind Peer Reviewed International Research Journal

Publisher: Global Journals

Online ISSN: 2249-460X & Print ISSN: 0975-587X

Dynamic Interplay: Unveiling the Biosphere-Geosphere Nexus in Carbon Cycling

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Abstract- A model describing the interaction of geological and biosphere processes is proposed. It is based on the postulate of the gravitational effect of the bodies of the solar system on the lithosphere plates' movement through magma flows and deep breathing of the Earth. The continuous movement of the plates consist of orogenic cycles. The cycles include a short-term orogenic periods of relatively fast plates' movement and long-term geosynclinal periods of relatively slow movement. The fast movement is caused by rifting, when magma breaks through the thin shell of the lithosphere and hardens in contact with sea water, forming a new plate. During the orogenic period, oceanic plates collide with the continental margin plate in the subduction zone. The energy of the collisions initiates thermochemical sulfate reduction, in which sedimentary organic matter (OM) is oxidized. The resulting CO₂ rises to the surface of the Earth, spreads over the planet, initiating photosynthesis. In the geosynclinal period due to the slow plates' movement the released collision energy is insufficient to initiate thermochemical sulfate reduction.

Keywords: lithosphere plates, rifting, orogenic cycles, orogenic and geosynclinal periods, evolution of photosynthesis, climatic and biotic cycles, gravity, thermochemical sulfate reduction, plate collisions.

GJHSS-B Classification: LCC Code: QE1-350.62



DYNAMIC INTERPLAY UNVEILING THE BIOSPHERE GEOSPHERE NEXUS IN CARBON CYCLING

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Dynamic Interplay: Unveiling the Biosphere-Geosphere Nexus in Carbon Cycling

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Abstract- A model describing the interaction of geological and biosphere processes is proposed. It is based on the postulate of the gravitational effect of the bodies of the solar system on the lithosphere plates' movement through magma flows and deep breathing of the Earth. The continuous movement of the plates consist of orogenic cycles. The cycles include a short-term orogenic periods of relatively fast plates' movement and long-term geosynclinal periods of relatively slow movement. The fast movement is caused by rifting, when magma breaks through the thin shell of the lithosphere and hardens in contact with sea water, forming a new plate. During the orogenic period, oceanic plates collide with the continental margin plate in the subduction zone. The energy of the collisions initiates thermochemical sulfate reduction, in which sedimentary organic matter (OM) is oxidized. The resulting CO_2 rises to the surface of the Earth, spreads over the planet, initiating photosynthesis. In the geosynclinal period due to the slow plates' movement the released collision energy is insufficient to initiate thermochemical sulfate reduction. The oxidation of OM does not occur and carbon dioxide does not enter the Earth's surface. Sulfate reduction turns out to be a regulator of the coupling of geological and biosphere processes. During the orogenic period, CO_2 fills the atmosphere and hydrosphere of the Earth. Its concentration becomes maximal as well as the rate of photosynthesis. During the geosynclinal period thanks to reduced plates' rate, the amount of CO_2 decreases as well as the rate of photosynthesis. The change in CO_2 concentration is accompanied by the change in oxygen concentration, which falls down due to reduced forms of metals coming to the Earth's surface in rifting. The change in the CO_2/O_2 ratio on the Earth's surface during the orogenic cycle controls the evolution of photosynthesis and results in climatic and biotic cycles on the Earth. In the second part of the work, numerous arguments, based on natural facts, on the analysis of chemical and isotopic data are considered. The most important provisions of the proposed mechanism are substantiated.

Keywords: lithosphere plates, rifting, orogenic cycles, orogenic and geosynclinal periods, evolution of photosynthesis, climatic and biotic cycles, gravity, thermochemical sulfate reduction, plate collisions.

INTRODUCTION

As early as 1926 V.I. Vernadsky (Vernadsky, 1926) developing Biosphere concept, put forward an idea on relationship of geologic and biosphere processes. This idea was put as the basis for the model of the global cycle of biosphere carbon (Ivlev, 2023). To study the processes that occurred in the past, we were guided by the principle of actualism, which claims that the laws of physics and chemistry are invariant in time. This allows applying them to the processes proceeding in the past, but taking into account the conditions that could have been at that time.

1. A MODEL OF GLOBAL CYCLE OF BIOSPHERE CARBON AND EVOLUTION OF GLOBAL PHOTOSYNTHESIS. PART I

The carbon pathway in the global cycle of biosphere carbon

To monitor the carbon pathway in global cycle of biosphere carbon consider Fig.1, in which it is depicted as a closed loop having two branches - reducing and oxidizing ones. The carbon of the natural "carbon dioxide - bicarbonate-carbonate ($\text{CO}_2 - \text{HCO}_3^- - \text{CO}_3^{=}$)" system feeds photosynthesis with a substrate CO_2 .

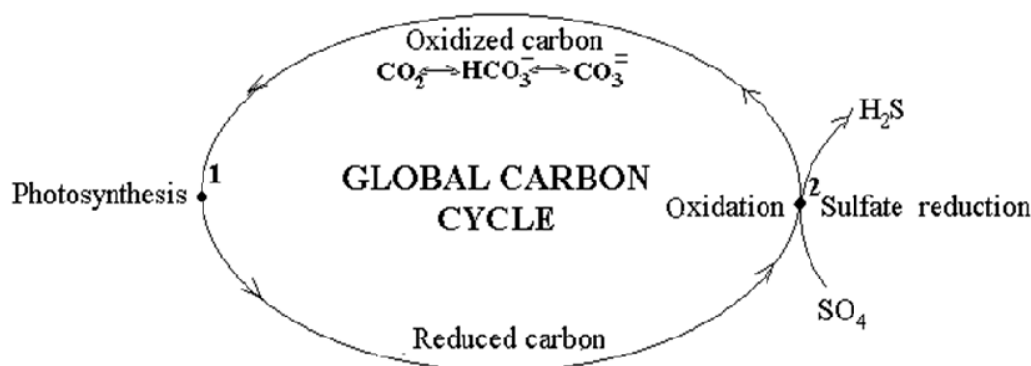


Fig. 1: Putative global carbon cycle in nature: oxidative and reductive branches. The points of carbon transition from the oxidative states to the reduced ones in photosynthesis (point 1) and back in sulfate reduction, proceeding in subduction zone (point 2).

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In this universal natural process, photosynthetic biomass is produced. Considering that it is used in trophic chains for the synthesis of heterotrophic biomass, photosynthesis can be regarded as a source of carbon for "living matter" as a whole with carbon atoms with varying degrees of reduction. After mass extinction of the "living" organisms, a sedimentary OM is formed. The residual reduced carbon is preserved in the earth's crust until it is subjected to full final oxidation in the subduction zone, the most submerged part of the crust (point 2). At this point, the global carbon cycle is completed.

From the occurrence of the "living matter", part of the reduced carbon, produced during photosynthesis, is oxidized to its initial state in the processes of respiration. The other part is oxidized in the subsequent processes of the aerobic and anaerobic zones of the earth's crust.

Now it is time to explain, why the cycle was named as biosphere one. In the natural " CO_2 - HCO_3^- - CO_3^{2-} " system, we excluded from the consideration, carbonate thicknesses since the chemical exchange of carbon atoms in solid state proceeds at an incomparably lower rate than carbon atoms in other components and physical states.

Fig.1 allows monitoring the movement of carbon atoms, but does not make it possible to understand the mechanism of the cycle's work. To study it, let's imagine a cycle in the form of a virtual machine consisting of geological and biosphere parts interacting with each other. Besides, the geological part is the leading one, since it sets the beginning of the work of the biosphere part and the sequence of biosphere events. But first, let's analyze the postulate that underlies all further reasoning.

The key postulate of the model on which subsequent proofs are based. On the probable cause of the uneven movement of lithosphere plates.

Due to the gravitational interaction of the Earth with the bodies of the near-solar system, streams of various liquids arise in the bowels of the Earth. These are flows of molten magma in the asthenosphere, hydrogen fluxes in degassing of the core, and flows of other gases and volatile components of a number of elements. The movement of fluids depends on various factors and has been poorly studied. The manifestation of motion is the continuous movement of lithosphere plates that cover the Earth, forming its solid shell. The lithosphere shell lies over the magma and it is known that the lithosphere plates' movement is uneven (Rutten, 1971; Martin, 1973; Flint, 1977).

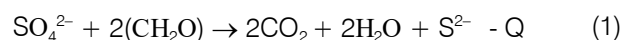
There is a short-term phase of rapid plate movement called the orogenic period, which coincides with the tectonically active state of the earth's crust. The state is characterized by intense volcanic and magmatic activity, including mountain formation. The long-term

phase of slow motion coincides with the tectonically calm state of the earth's crust. The phase of quiet movement of lithosphere plates is called the geosynclinal period. Both periods form an orogenic cycle that repeats itself in geological time. Some researchers call this sequence of processes the "pulse of the Earth" (Rutten, 1971), others - the "uneven deep breathing of the Earth" (Dobretsov et al., 2001; Letnikov, 2001; Podkletnov). If to stick to the comparison with respiration, then, according to its sense, it can be argued that at the moment of increased respiration in the thinnest part of the lithosphere shell (in the zone of mid-oceanic ridges), magma, together with its accompanying components, breaks the lithosphere shell and comes into contact with oceanic water solidifies, forming a new plate. This pushes the adjacent plates apart, forcing them to move. Thus the intensification of deep breathing of the Earth, including the process of rupture of the lithosphere shell and the subsequent formation of a new plate, is called rifting.

It is natural to assume that the time of acceleration of the lithosphere plates' movement coincides with the time of the orogenic period. At the same time during the long-term geosynclinal period plates' movement slows down as well as tectonic activity. Let's see now, how the described sequence of the processes affects the functioning of the global carbon cycle.

In the deeply submerged zone of the Earth's crust (in the subduction zone), oceanic lithosphere plates collide with the margin of the continental plate. Being smaller in size, oceanic plates sink into magma and dissolve in it. The continental plate rises at the collision site and participates in mountain building.

But the main result of lithosphere plates' collisions in the orogenic period is that the released energy of the accelerated plates collisions initiates thermochemical sulfate reduction, in which gypsum, formed from seawater, oxidizes sedimentary organic matter that has descended from the surface into the subduction zone



Carbon dioxide formed during the orogenic period as a result of the oxidation of OM enters the Earth's surface, filling the atmosphere and hydrosphere of the Earth, then spreads around the planet initiating photosynthesis in different locations in accordance with the local conditions.

In geosynclinal period due to the slow plates' movement the energy, released during collisions, is no longer sufficient to initiate sulfate reduction reaction. That is why, there is no OM oxidation and the main geological processes during this period are weathering, erosion and denudation.

Thus, the main difference between the processes in orogenic and geosynclinal periods is that

in orogenic periods active collisions lead to the oxidation of sedimentary OM in the subduction zone and to the initiation of photosynthesis in the biosphere, whereas in the geosynclinal period there is no oxidation of OM in the subduction zone. This makes adjustments to the dynamics of the orogenic cycles, in particular, to the dynamics of biosphere processes.

Let's consider the features of the processes in the biosphere part of the virtual machine during the orogenic period. It is believed that in the orogenic period, when the oxidation of OM occurs, the concentration of CO_2 reaches its maximal values. This also determines the maximum values of the photosynthesis rate. Due to the greenhouse properties of CO_2 , high temperatures prevail on the Earth's surface. Based on the above, it can be concluded that high temperatures and anaerobic conditions, that arise due to the entry of igneous rocks to the surface, characterize the living conditions in the biosphere during the considered period.

During the geosynclinal period, CO_2 does not flow from the subduction zone, but photosynthesis goes on the Earth. As a result, the concentration of CO_2 in the environment decreases, whereas oxygen content grows. In parallel with the decrease in CO_2 concentration, the surface temperature on the Earth decreases and by the end of the geosynclinal period glaciations occur. Such a change in habitat conditions leads to a biotic cycle. The predominance of thermophilic anaerobes at the beginning of the cycle (in the orogenic period) is replaced by the dominance of frost-resistant aerobes by the end of the geosynclinal period of the cycle.

With the change of orogenic cycles, the low-temperature and high-oxygen conditions of the geosynclinal period of the previous cycle abruptly change to the high-temperature anaerobic conditions of the orogenic period of the current cycle (Thunell et al., 1984). A number of the "living" organisms adapted to other conditions die (Gorican et al., 2013) and a huge amount of biogenic material enters the sediment. It gives rise to formation of sediments rich in OM ("black shales") (Ivlev, 2019; 2023).

In this form without involving additional arguments the model allows explaining biosphere events that have been already known to geologists and paleontologists, such as alternation of periods of warming and glaciations, periodic mass extinctions of living organisms, etc. It evidences for the reasonable basis of the model. We will return later to other arguments justifying the model, but now we shall consider some key items arising from the use of the model.

Global photosynthesis is the key process operating in the biosphere part of the global carbon cycle

The main process in the biosphere part of global carbon cycle model is global photosynthesis,

which takes into account the cumulative result of photosynthesis of the entire ensemble of organisms living on the Earth at the time under consideration.

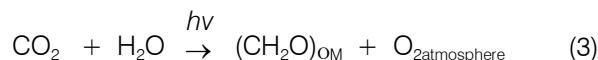
When considering the process, it is important to answer two questions: 1) whether the equation, which is commonly used for description of traditional photosynthesis is applicable to describe global photosynthesis; 2) whether the properties of global photosynthesis differ from those of traditional photosynthesis.

Traditional photosynthesis is understood as a process in the simplest "organism - environment" system, which proceeds in the mode of the substrate depletion and is written as follows (Ivlev, 2020):



It follows from the analysis of expression (2) that in traditional photosynthesis, the changes in concentration of substrate (CO_2) and product (O_2) of the reaction should be antiphase, while changes in the concentration reaction products $(\text{CH}_2\text{O})_{\text{biomass}}$ and (O_2) are in-phase.

It was previously shown (Ivlev, 2019) that under certain assumptions global photosynthesis can be expressed by exactly the same equation as traditional one



only in the right part, instead of synthesized biomass, there is a mass of sedimentary OM, and instead of synthesized oxygen, there is oxygen content in the atmosphere at the moment.

It remains to be convinced that expression (3) gives the same connections between substrates and products of global photosynthesis as the expression for traditional photosynthesis. To prove it replace the variables used to describe the theoretical relationship for traditional photosynthesis, the empirical relationship, observed between the rate of the substrate (CO_2) loss and the rate of photosynthetic product (O_2) accumulation in the Phanerozoic was used (Fig.2) as well as the relationship between the rate of accumulation of photosynthetic products (the rate of O_2 production and the rate of OM synthesis). Instead of the OM synthesis rate, in the latter case, a sedimentation rate proportional to it is used.

Figure 2 shows the antiphase connection between the substrate $(\text{CO}_2)_{\text{atm}}$ and the products $(\text{CH}_2\text{O})_{\text{OM}}$ and O_2 of global photosynthesis for the Phanerozoic, obtained using the Geocarb III model.

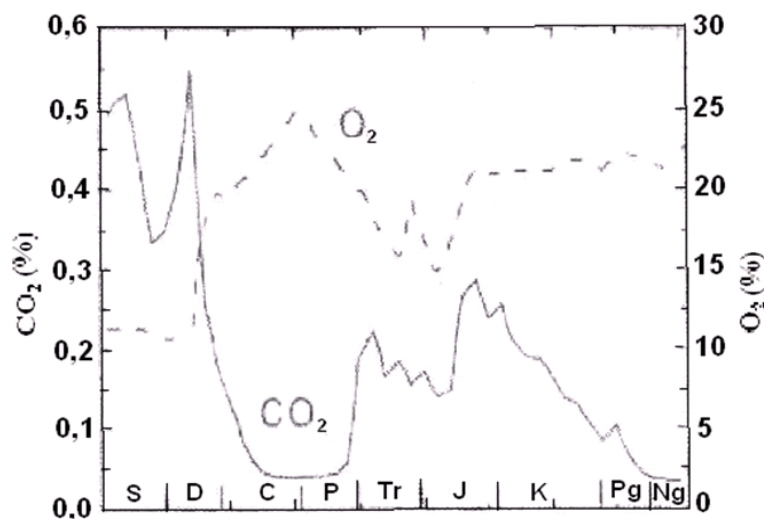


Fig. 2: Antiphase character of changes in the CO_2 substrate (solid line) and the O_2 product (dashed line) of the photosynthesis reaction in the Phanerozoic according to the calculation results using the Geocarb III model (Igamberdiev, Lea, 2006)

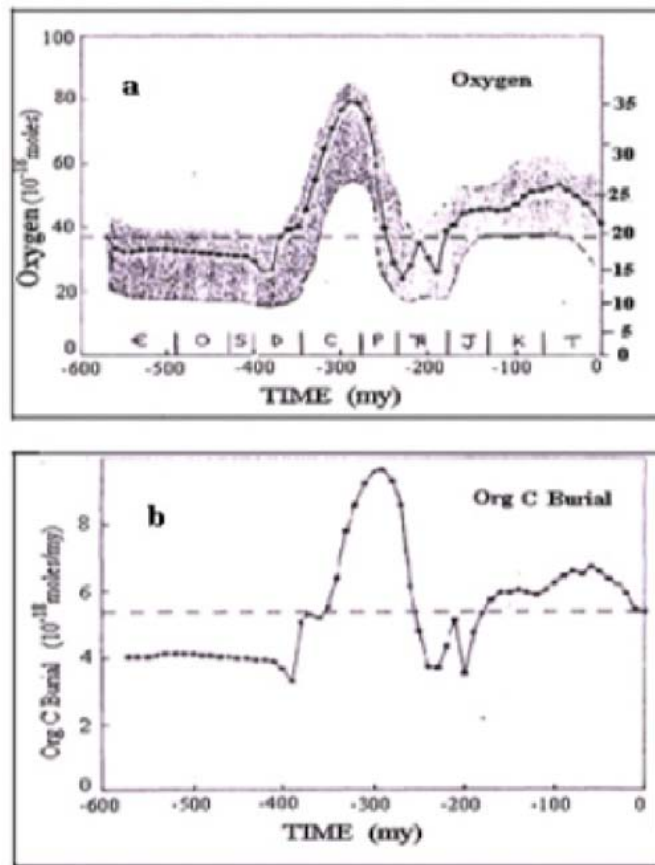


Fig. 3: The in-phase changes of oxygen content in the atmosphere (a) and burial organic matter rates in the sedimentary rocks in Phanerozoic.

Figure 3 shows the in-phase relationship between the products of global photosynthesis (atmospheric oxygen and the sedimentation rate of organic matter), calculated using the model (Berner, Canfield, 1989) for the Phanerozoic.

The fact that the curves describing the consumption of substrates and the yield of products during global photosynthesis in the Phanerozoic, obtained using geological models, are similar to the curves for traditional photosynthesis proves that global

photosynthesis really functions in the biosphere part of global carbon cycle.

Properties of global photosynthesis. The evolution of global photosynthesis within the global cycle of biosphere carbon and in geological time (Ilev, 2023).

It follows from the definition of global photosynthesis that its properties should be close to those of traditional photosynthesis. For the convenience of describing these properties, one should imagine a conditional photosynthesizing organism, the properties of which are obtained by averaging the properties of the ensemble of organisms. Such an organism should have all the properties except the ontogenetic ones related to age.

Global photosynthesis, like traditional one, consists of two oppositely directed reciprocal processes - CO_2 assimilation and photorespiration. Taking into account the principle of actualism related to the global carbon cycle, it can be argued that CO_2 assimilation is responsible for accumulation of sedimentary OM, while photorespiration reduces it. Moreover, an increase of the CO_2 concentration in the environment increases the accumulation of sedimentary OM in the Earth's crust, and an increase in the concentration of O_2 in the atmosphere decreases it. According to the proposed model of the global carbon cycle, the rate of sedimentary OM accumulation is maximal in the orogenic period of the cycle and begins to decrease to the minimum in the geosynclinal period, reaching it by the end of the period.

The second important property is the ability to fractionate carbon isotopes. The signs of isotopic effects are opposite: Assimilation of CO_2 is accompanied by enrichment of OM in ^{12}C , photorespiration is accompanied by enrichment of OM in ^{13}C . According to the mechanism of the global carbon cycle, the most light carbon isotope composition is formed in the orogenic period of the cycle. In the geosynclinal period, there is an enrichment of OM carbon in ^{13}C , which increases by the end of the period. It should be recalled that the enrichment of OM in ^{13}C in the geosynclinal period occurs not only due to accumulation of oxygen in the atmosphere and corresponding increase of photorespiration, but also due to the effect of CO_2 depletion in the "atmosphere-hydrosphere" system because of photosynthesis (Rayleigh depletion isotope effect).

After getting acquainted with the basic properties of global photosynthesis, it is possible to consider its evolution basing on the proposed model and the available factual material. It is easy to see that the nature of the evolution of photosynthesis in a separate orogenic cycle and during geological time differ.

In a separate orogenic cycle, the evolution of photosynthesis has a pulsation character. Indeed, given

the short duration of the orogenic period, the CO_2 injections coming from the subduction zone can be considered as pulsations. Carbon dioxide that fills the Earth's "atmosphere-hydrosphere" system and achieves maximal values, then gradually decreases during long-term geosynclinal period up to the minimal values thanks to photosynthesis as well as, cooling and glaciation by the end of the geosynclinal period gives one more confirmation in favor of the idea of the pulsation character of evolution of the global photosynthesis within a separate orogenic cycle.

In geological time the evolution of global photosynthesis has a different mode. Each new orogenic cycle begins at a lower CO_2 concentration level and ends at a higher oxygen concentration level as compared with the previous orogenic cycle. This allows saying that evolution during geological time occurs stepwise but steadily progressively in the direction of an increase in oxygen content and a decrease in CO_2 concentration.

The idea on global photosynthesis evolution allow us considering the question of how the accumulation of sedimentary matter in the Earth's crust and oxygen in the atmosphere occurred.

The idea of global photosynthesis evolution allows considering the question of How did the accumulation of OM in the Earth's crust and oxygen in the atmosphere occur?

From the properties of global photosynthesis described earlier, it clearly follows that CO_2 assimilation is responsible for the accumulation of OM in the Earth's crust, and photorespiration is responsible for the decrease of accumulated OM. It is also obvious that photorespiration increases over time, as oxygen accumulates during the evolution of global photosynthesis. This is supported by Table 1, although accuracy of the data provided in it, obtained by different authors, is rather low, the trend is quite obvious. This means that in the course of geological time, the accumulation of OM in the earth's crust decreases.

Table 1: Estimates of the average concentrations of O₂ in the atmosphere during geological time, obtained by different models.

Eon / Era Numerical age Ma	Approximate Value	References
Precambrian/ Paleoproterozoic 2200 – 2000	~ 0,2 %	Holland 1998; Bjerrum, Canfield, 2004
Precambrian/ Neoproterozoic 1700 – 570	2 – 3 %	Canfield, Teske, 1996
Phanerozoic/ Cambrian– Devonian 570 – 350	< 15 – 17 %	Berner, Canfield, 1989; Berner et al, 2000; Berner, 2003
Phanerozoic/ Carboniferous– Permian 350 – 230	25 – 30 %	Lenton, 2001
Phanerozoic/ Mesozoic Triassic – Cretaceous 230 - 145	20 %	Lenton, 2001; Bergman et al., 2004
Phanerozoic/ Cenozoic / Neogene / Miocene 23	23 %	Berner, Kothavala, 2003

Within the frames of model, the OM accumulation in the Earth's crust may occur only in the orogenic period of the cycle, since namely in this period the CO₂, substrate for assimilation, enters the Earth's surface from the subduction zone. In the geosynclinal period CO₂ is not enter onto the Earth's surface but photosynthesis goes on, i.e. CO₂ is consumed. Therefore, it can be argued that over time (with the repeated orogenic cycles), two trends work in the accumulation of OM in the earth's crust: the accumulation of OM in the crust goes on, but with each new cycle, the accumulation becomes less and less, i.e. the accumulation OM increment strives to 0 because of the increasing photorespiration.

This will go on until the accumulation of OM in the earth's crust stops, while the accumulation increment becomes 0. At the same time the oxygen content in the atmosphere, in accordance with the equation for global photosynthesis, stabilizes.

We called this state of the global carbon cycle by the point of ecological compensation. A similar state in traditional photosynthesis is called the compensation point (Edwards, Walker, 1983). It corresponds to a state where the contribution of photorespiration to plant metabolism becomes comparable to the contribution of CO₂ assimilation. Global photosynthesis differs from traditional photosynthesis in that its evolution is always going in one direction, while the oxygen concentration increases all the time, as well as photorespiration. This is confirmed by the observed enrichment of biomass in ¹³C over time (Garrels, 1975; Hayes et al., 1999; Andrusevich et al., 1998; 2000).

Upon reaching the state, the system goes into a stationary state, in which all characteristics begin to oscillate around some average values (Ivlev, 2023).

Table 1 confirms this presentation. As shown from the Table 1, it is obvious that the oxygen content rapidly increases in the atmosphere up to the Carboniferous-Permian epoch, where it gets maximal meaning. Then there appeared significant fluctuations around this value. This may be considered as an approximation to the ECP, where the oxygen content achieves stationary state, and therefore the accumulation of OM in the earth's crust does not occur.

In the ECP state, all the characteristics of the global carbon cycle become oscillatory. Fluctuations occur near some stationary averages. The data presented in Table 1, although empirical and approximate, allow us to see how the oxygen saturation of the atmosphere changes. As can be seen from Table 1, the oxygen concentration increased rapidly until the period. After that, the increase in oxygen content is completed, which indicates the frequency of the proximity of the ECP state.

II. ARGUMENTS AND FACTS SUBSTANTIATING THE MODEL OF GLOBAL REDOX-CYCLE OF BIOSPHERE CARBON. PART II

1. Chemical and isotopic data prove the oxidation of sedimentary sediment OM in the subduction zone with the participation of thermochemical sulfate reduction.

Fig. 4 shows the data of Mackenzie and Piggot (Mackenzie, Piggot, 1981), who studied the secular variations of carbon isotope composition of marine carbonates and sulfur isotope composition of marine sulfates covering Proterozoic and Phanerozoic. The curves display an amazing synchronicity. Given the probable connection of these curves with the oxidation

reaction of OM and with the reaction of thermochemical sulfate reduction, this synchronicity indicates, that these reactions are somehow related.

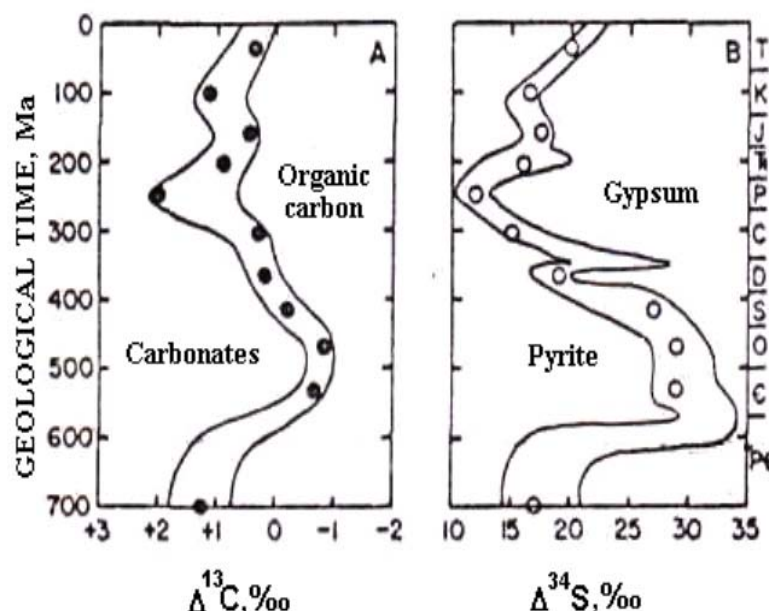


Fig. 4: Synchronous variations in the carbon isotope composition of marine carbonates and those sulfur isotope composition of marine sulfates in the Proterozoic and Phanerozoic (Mackenzie, Piggot, 1981).

At the bottom and at the top the curves have two humps oppositely directed (Fig.4). Next to the humps on the curves, the authors made inscriptions indicating the widely spread minerals corresponding to the time intervals of mentioned humps. If examine closely Fig.4, it is easy to find that the lower humps correspond to carbonates and sulfides which are the products of the sedimentary OM oxidation by means of the sulfate reduction. If to address to the upper humps, which the authors link to the prevalence of the sulfates and the rocks, rich in OM, one should conclude they are likely the substrates of the same reactions.

Note, If this assertion is true the opposite directions of humps become clear. This conclusion, based on the analysis of chemical data, are confirmed by the isotopic data based on the analysis of isotope fractionation in the chemical reactions under study.

As shown, the lower hump on the right curve (Fig.4) is directed to the right, what indicates that sulfate reduction occurs, causing their ^{34}S enrichment. At the same time, the hump on the left curve corresponds to the enrichment of carbonates with the isotope ^{12}C . This is due to the fact that when sulfate reduction takes place, the oxidation of hydrocarbons proceeds in parallel. The CO_2 produced in this case inherits the "light" isotope composition of the OM, since its complete oxidation occurs. Therefore, when CO_2 , enriched with the isotope ^{12}C , enters the marine "carbon dioxide - bicarbonate - carbonate" system, which carbon more enriched in ^{13}C , the total carbon of the marine system

becomes enriched in ^{12}C . The more complete the sulfate reduction is, the more enriched in ^{12}C the carbon of the natural marine system becomes.

One more indirect argument in favor of the above assertion can be given. At the early stages of the evolution when oxygen content in the atmosphere was low, some amount of H_2S , produced in sulfate reduction, achieved the Earth's surface. It was the reason for the widespread distribution of sulfate-oxidizing bacteria, the prevalence of which was so great that the authors of the work below came to the conclusion that their bacterial biomass was the main supplier (Hayes, 1983) for the OM at that time.

- Experimental confirmation of the model's conclusion about the regular sequence of biosphere processes.

The suggested mechanism of the redox-cycle of biosphere carbon functioning implies a regular sequence of biosphere events due to the coupling of physico-chemical processes acting in the cycle. It can be traced in the changes of some parameters.

Investigating long-term fluctuations in the carbon isotope composition of marine carbonates in the Proterozoic Derry and colleagues (Derry et al., 1992) have discovered regular variations of the parameter. They used not only their own data, but also those available from the literature. But the cause of regular changes with time, which were clearly visible from the data the authors could not explain.

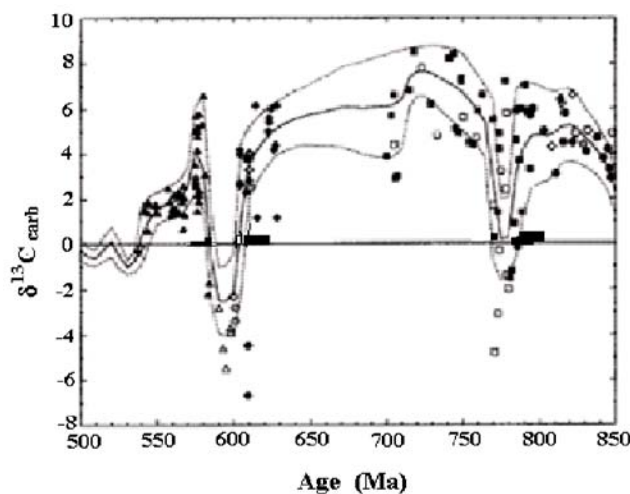


Fig. 5: Long-term variations of $\delta^{13}\text{C}$ marine carbonates in the Late Proterozoic. The samples were taken from various stratigraphic groups (Derry et al., 1992).

However, these isotopic variations are easily explained within the framework of the proposed mechanism of the carbon redox-cycle. Indeed, imagine that the negative excursions of $\delta^{13}\text{C}$ carbonates are the peaks, corresponding to the changes in the parameter during the orogenic periods of two consecutive orogenic cycles. This is supported by their negative values and by the fact that the peaks are narrow, and hence the periods are short. Negative values indicate the association of peaks with the oxidation of OM in sulfate reduction. In addition, negative peaks in orogenic periods are confirmed by the fact (see later) that they are associated with the influx of chemical elements from igneous rocks and with the formation of rocks rich in organic matter ("black" shales) (Kendall et al., 2006; Ivlev, 2023).

The adjacent part of the cycle is wide, what indicates that it corresponds to a long-term geosynclinal period. In addition, it corresponds to more positive values of $\delta^{13}\text{C}$, protruding in the opposite direction. But the most convincing argument is the following. As it follows from the mechanism of the cycle, glaciations should occur at the end of the geosynclinal period, before the onset of a new cycle. Really, before the beginning of each cycle there are the rectangles, filled with black. They show that before the first cycle there was a Varangian glaciation (~780 Ma), before the second cycle there was a Sturtian glaciation (~600 Ma).

Young (Young, 2015) also discovered the existence of long-term cyclic fluctuations in the isotopic composition of marine carbonates in almost the same time interval. They manifested themselves in the form of negative excursions of $\delta^{13}\text{C}$ carbonates, which were preceded by glaciations. Besides he found that the appearance of negative peaks was accompanied by mass extinction of organisms associated with the increase in the level of radioactivity. However the extinction might be the result of abrupt climatic changes

though it might be partly the result of radiation. In other words, the signs described by Young are quite consistent with the regular sequence of events predicted from the model. The high level of radiation is explained by the arrival of radioactive elements from the depths along with igneous rocks in rifting. Thus, the predicted of physically justified regular sequence of biosphere events can be considered as an argument in favor of the model.

3. The stratigraphic unevenness of the distribution of world oil reserves and the number of discovered deposits in the territory of the former USSR proves the existence of orogenic cycles.

Some geologists have revealed a stratigraphic unevenness in the distribution of world oil reserves (Vyshemirsky, Kontorovich, 1997) and an almost synchronous unevenness in the distribution of the number of discovered fields (Korchagin, 2001).

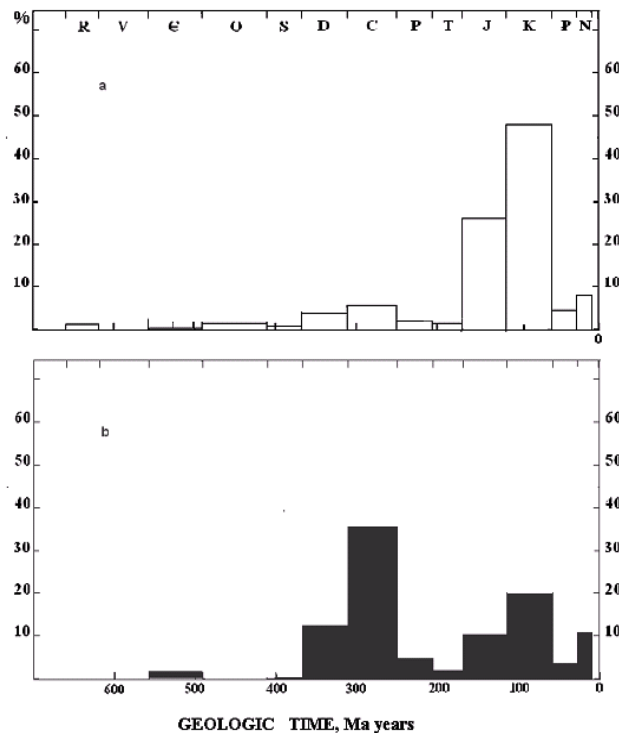


Fig. 6: The comparison of the stratigraphic distribution of the initial explored recoverable oil reserves by the largest oil-bearing basins of the world (Vyshemirsky, Kontorovich, 1997) (a) and the distribution of oil deposits by stratigraphic complexes (b) (% of the number of deposits in the complex from the total number in the territory of the former USSR (Korchagin, 2001).

The fact that the spikes in the distribution of world oil reserves and in the number of the discovered oil fields occur at approximately the same intervals of geological time indicates that they are caused by the reasons related to the change of orogenic cycles. The first spike dates back to the Riphean, to the period when the first industrial oil fields were discovered. It is notable, it appeared much later than the appearance of photosynthesis (about 2.2 billion years ago). Since, in accordance to the model, in order for industrial accumulation of oil to appear, it takes time for the necessary amount of OM to accumulate, it takes time for its transformation and maturation, the time for the emigration and accumulation of hydrocarbons in traps. In other words, the discovery of oil fields before the Riphean is extremely unlikely. From the other side, taking into account the presence of ECP, one can expect that since Miocene, when ECP occurred, the accumulation of OM in the Earth's crust has ceased and oils as well.

4. The study of the carbon isotope composition of oils is another argument in favor of the existence of orogenic cycles and the evolution of global photosynthesis.

Another parameter that can be used to monitor the functioning of the global carbon cycle and obtain arguments to justify the key points of the model is the isotopic composition of oil carbon.

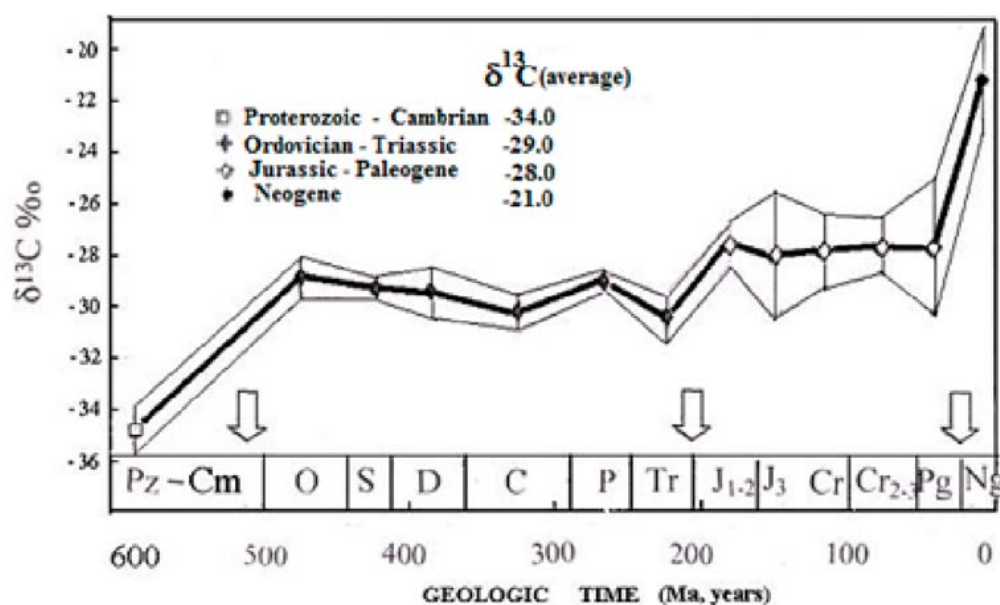


Fig. 7: The change of the average carbon isotope composition ($\delta^{13}\text{C}$, ‰) for saturate fraction C15+ of crude oils. Vertical bars are standard deviations, which increase with decreasing age. Arrows indicate Cambrian – Ordovician, Triassic – Jurassic, and Paleogene–Neogene boundaries where ^{13}C enrichment of oil carbon occurs (Andrusievich, et al., 1998, 2000).

Figure 7 shows a curve illustrating the changes in the carbon isotope composition of oils of different ages and origins. Andrusievich and colleagues (Andrusievich et al., 1998) have studied a collection of 513 oils for the period from the Proterozoic and Phanerozoic inclusive. The authors found changes in the carbon isotope composition of oil over four time periods. On the arrow of geological time from the Proterozoic to the Neogene, they found four stages of change in the isotopic composition of carbon. Moreover, the direction of the enrichment of carbon in oil with the isotope ^{13}C is clearly traced with each step appearing in time. Oil is increasingly enriched with a heavy isotope, with increasing age, as predicted by the model. The explanation is based on an increase in the photorespiratory activity of global photosynthesis due to an increase in the oxygen content in the atmosphere. The same trend, but using the example of the isotopic composition of carbon OM, was previously noted by Garrels (Garrels, 1974). Following the logic of the model, the observed stages of changes in the carbon isotope composition of oils are related to the sequence of orogenic cycles throughout the evolution of photosynthesis.

One more detail should be noted on Fig. 2. The spread of $\delta^{13}\text{C}$ values has become noticeably larger since the Jurassic. The fact is that by this time photosynthetic Life had finally conquered the land with all its diverse environments. The number of parameters, on which photosynthesis and its isotopic fractionation depend, has increased. This is the reason for the spread of $\delta^{13}\text{C}$ values.

- The model of global redox-cycle of biosphere carbon is capable to substantiate and explain the origin and conditions of "black shale" formation and the associated traits and geological objects as well.

Most geochemists, having studied the "black shales" origin came to the conclusion that their formation occurred under conditions of oxygen-free phenomena in the ocean (OAE) (Arthur, Schlanger, 1979; Arthur et al., 1987). This is in a good agreement with the model of the global redox-cycle of biosphere carbon considered by us. According to the model, oxygen-free events occurred during short orogenic periods (Twenhofel W. H. (1939) Thunell et al., 1984) that coincide with rifting, when magma breaks through the lithosphere, turning into a new plate. Along with magma, other endogenous fluids penetrated through the lithosphere, including reduced forms of metals, simultaneously with other components of the Earth's deep breathing.

The reduced forms of endogenous elements, reacting with atmospheric oxygen, led to anoxic conditions. The mass extinction of organisms, caused by abrupt change of climatic conditions, ensured the formation of deposits rich in organic matter, which later turned into "black shales" (Bazhenova, Sokolov, 2002). The model not only reasonably explained the formation of "black shales", but also quite clearly described the traits accompanying their formation (see later).

According to the various estimates, the CO_2 content in the periods of the OAE increased 5-6 times, for example, during the OAE in the Cretaceous it reached 2000 ppm (cf. with a modern content of 380 ppm). With the onset of the greenhouse period the

temperature of the surface waters of the ocean increased by 7-13 °C (Erba, Bottini, 2009). Anoxia and a sharp increase in temperatures caused the mass extinction of organisms. This brought about drastic changes in the abundance and taxonomic diversity of fossil biota (Yudovich, Ketris, 2015).

The fact that the formation of "black shales" occurred when combined with the mineral part of almost any composition (clay, sand-siltstone, carbonate, siliceous, tuff, etc.) with organic part in a variety of polyfacial conditions (lake, delta, littoral, lagoon, shallow, shelf, etc.). This evidences that formation of sediments, rich in organic matter, is due to objective processes accompanying the change of orogenic cycles.

On the cause of high sulfurization of OM and oil of "black shales" rocks

A typical feature of the "black shales", their high sulfur content, has long been noticed by oil geologists. Sometimes it can reach 10%. High sulfur content was firstly found in domanic (Baturin, 1978). These rocks are also referred to as "black shales". The high sulfur content was confirmed Parparova (Parparova, 1975) and Kontorovich (Kontorovich, 1976). Moreover, high sulfur content is often combined with the presence of pyrite (FeS₂) (Yudovich, Ketris, 2015), which has two sulfur atoms in its composition. The question arose, what was the source of sulfur?

It is still believed that the sulfurization of OM occurs at the interaction with hydrogen sulfide, which is formed during the microbiological reduction of sulfate in the near-surface anaerobic zone of the diagenetic transformation of OM. It is obvious that the oxidizer in this case is seawater sulfate (Volkov, 1984). In order for such a reaction to take place, it is necessary that the conditions for the course of sulfate reduction and the vital activity of bacteria, as well as there should be a certain degree of transformation of OM with multiple carbon bonds and atoms capable of being replaced by sulfur atoms. Although it is very difficult to find such a combination of conditions in nature, but no other alternatives have been proposed. The global biospheric carbon cycle model offers an alternative explanation. Let's consider the abiogenic thermochemical reduction of sulfates, which occurs in the subduction zone and is used for OM oxidation.

In addition to the above data from the work of Mackenzie and Piggott (Mackenzie, Piggott, 1981), which prove the existence of the thermochemical sulfate reduction in subduction zone, there are data, obtained Shaver et al (Shaver et al., 2018), evidencing on activity of sulfate reduction in the depth and thus indirectly confirming the participation of hydrogen sulfide in OM and oil sulfurization. They found that sulfur isotope composition of pyrites is significantly enriched in ³²S as compared with sulfur of OM. We explain this interesting fact as follows.

Hydrogen sulfide, formed in the subduction zone in sulfate reduction, along with the produced CO₂, passes the zone of "active" (reduced) iron, which binds H₂S. Only after that, the excess amount of H₂S penetrates into the upper layers, where it participates in binding reactions with OM. Remind, the thermochemical sulfate reduction reaction is accompanied by the Rayleigh effect, according to which H₂S, formed at a deeper degree of sulfate conversion, turns out to be enriched in ³⁴S. Hydrogen sulfide, formed in the subduction zone in sulfate reduction, along with the produced CO₂, passes the zone of "active" (reduced) iron, which binds H₂S. Thus, the combination of temporal isotopic differences in the producing H₂S in course of sulfate reduction with the spatial separation of the pyrite formation zone and the zone of interaction of OM with H₂S explains the observed isotopic differences.

The nature of abnormal geochemical associations of "black shales" with compounds of rare metals and rare earth elements.

Geologists have long noticed the association of "black shales" with powerful geochemical anomalies represented by compounds of rare earths and metals (Mo, V, Re, Hg, Ni, etc.) (Yudovich, Ketris, 2015; Herazo et al., 2021). The question is, what connects these completely independent biosphere processes: "black shales" formation and geochemical association. The pathway of "black shales" formation was described by the global carbon cycle model. The dominance of volcanic and volcanogenic rocks in the area of the metal association formation supports the idea on volcanic origin of the associations (Twenhofel, 1939). The question remains, what connects these seemingly completely independent processes.

To answer this question, let's see if both processes have a common point of contact. The analysis shows that such a point is rifting, i.e. the moment when the magma flow with the flow of deep fluids, consisting of volcanic gases that include volatile compounds of elements, breaks through lithosphere shell. Further, the destinies of both flows develop independently. Magma flow forms new lithosphere plates, the collisions of which stimulate biosphere processes on the earth's surface. The processes, described above, compose pathway, which can be called "biosphere" pathway.

It can be briefly described as follows. Carbon goes through the stage of photosynthesis, the formation of a "living" matter which dies at orogenic cycles change, forming sediments, rich in OM. "Black shales" are formed during the subsequent transformation of sedimentary OM. The cycle change occurs in the short orogenic period of the cycle when deep fluids along with magma break through the lithosphere shell.

During the orogenic period, volatile compounds of metals, carried by volcanic exhalations, get onto the Earth, form a geochemical association, which is bound

to "black shales" because both processes occur at the same time (orogenic periods of the cycle) and originate from same source (inner fluids of Earth breathing).

6. Long-term recurring fluctuations in the content of trace elements in seawater are an argument in favor of the global carbon cycle model.

Long-term cyclic variations of the concentrations of bio-essential trace elements (molybdenum, selenium, cadmium, and thallium) and

macro-element phosphorous, first was revealed in the Proterozoic by Zerkle and colleagues (Zerkle et al., 2005). Later the fluctuations were described by Large and colleagues (Large et al., 2015). They found that Phanerozoic seawater also demonstrated the same fluctuations of spread from maximum to minimum. The maximum corresponded with a period nutrient rich ocean and vice versa.

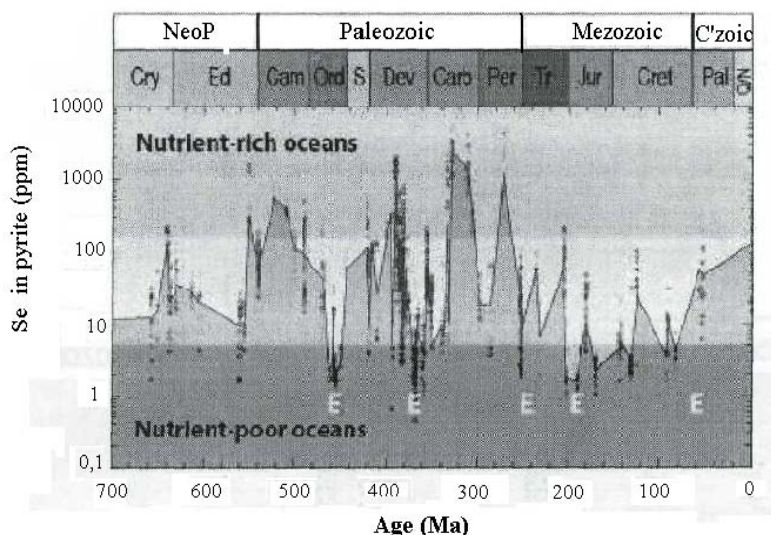


Fig. 8: Temporal pattern of Se in marine pyrite. The gray area, which covers the curve of selenium variations from above, shows an ocean rich in bio-essential microelements. The black bottom area, which covers the curve of selenium variations from below, characterizes the ocean poor in bio-essential microelements. E denotes the fixed times of mass extinctions on a geological scale (Large et al., 2015).

The distinct cyclic variations were confidently confirmed by statistical processing of the material, using Spearman correlation coefficients. The results of the mathematical treatment show the cyclic character of TE variations, which begin with volcanism and end with full depletion of TE and by extinction of organisms. The variations of selenium, one of the most indicative elements, is presented on Fig. 8.

A comprehensive study of long-term fluctuations in seawater reveals a direct analogy between the formation of geochemical associations of "black shales" with rare metals and fluctuations of trace elements in seawater. The model of the global redox cycle of biospheric carbon allows displaying this analogy and explaining the nature of this relationship. Two items should be paid attention to.

First, the nature of metals in geochemical association with "black shales" and the composition of trace elements in seawater are unanimously associated with volcanic activity or, taking into account what was said earlier, with deep breathing of the earth.

Secondly, volcanic emissions and volatile compounds of elements, including metals, which together with the magma break through the lithospheric shell, forming a new plate during rifting. These

processes coincide with the orogenic period of plate's movement. The further fate of metals making an association with "black shales" and the formation of the "black shales" themselves were discussed above.

Volcanic ash, and igneous rocks brought to the Earth's surface with volcanic exhalations are exposed to the environmental action. The microelements contained in them are leached out. Meteor waters carry solutions of trace elements into the ocean. From there they fall into the sediment. It is obvious that the maximum concentrations of TE are achieved during the orogenic period. During the geosynclinal period, they are used as nutrients by the inhabitants of the oceans and their concentrations drops to the minimum.

It should be noted that the content of trace elements in seawater cannot be measured directly. It was proven that TE content of marine sedimentary pyrite in black shales is a good approximation of characteristics of oceanic water. This can be also explained using the model in question. It follows from the above that the iron participating in the formation of pyrite enters the sedimentary strata, like other trace elements, during the same orogenic period. In the same time the formation of "black shales" occurs. After the absorption of pyrite by the "black shale", trace elements

do not participate in the processes in seawater. And therefore, the composition of trace elements preserves the memory of the original composition in seawater.

III. CONCLUSIONS

The idea of V.I. Vernadsky on the interaction of geological and biospheric processes is considered and a probable mechanism based on the postulate of the gravitational effect of solar system bodies on the movement of lithospheric plates is proposed.

The impact leads to complex magma flows in the asthenosphere and deep breathing of the Earth, in the form of hydrogen stream coming from the core, which is joined with volatile compounds of other elements. The lithosphere shell changing, reflects these processes. When spreading, it expands and become thin. Then rifting comes, in which magma, along with other fluids, breaks through the lithosphere shell and, in contact with oceanic water, solidifies, forming a new plate. The described internal processes manifest themselves in the form of uneven and continuous movement of lithosphere plates moving along the surface of molten magma.

The movement of lithosphere plates is cyclical. Cycles are called orogenic and consist of two periods. A short orogenic period of relatively rapid plate movement coincides with rifting. In parallel with the formation of a new plate, some of the fluids erupt in the form of volcanoes and lava flows. A new plate, pushing apart neighboring plates, causes their accelerated movement. In the subduction zone, oceanic plates collide with plates of the continental margins. Smaller in size oceanic plates sink into magma and dissolve in it. The continental plate rises and participates in mountain formation.

The most important result of collisions in the subduction zone during the orogenic period is that the energy released in them leads to the activation of thermochemical reduction of sulfates, in which the OM is oxidized. The CO₂ formed during oxidation rises to the surface, initiating photosynthesis there.

During the long geosynclinal period of the plate movement cycle, the released collision energy turns out to be insufficient to initiate thermochemical sulfate reduction and oxidation of organic matter does not occur. Carbon dioxide does not reach the Earth's surface.

In the biosphere on the Earth's surface, maximum concentrations of CO₂ are achieved during the orogenic period, and taking into account the greenhouse properties of this gas, maximum temperatures are achieved as well. The reduced metals of igneous rocks rising with the lava react with atmospheric oxygen, making the environment anaerobic. The rate of photosynthesis is maximal.

In the geosynclinal period, due to the lack of CO₂ input from the subduction zone, its concentration begins to fall and becomes minimal by the end of the period. The temperature also drops until glaciations. On contrary, the oxygen concentration, is growing up.

A joint consideration of the changes in environmental parameters during the orogenic cycle allows asserting that the evolution of global photosynthesis within a separate orogenic cycle on the Earth's surface, controlled by the CO₂/O₂ ratio, has a pulsatory character, and evolution during geological time has a stepwise progressive character. As a result, climatic cycles and a biotic turnover arise on the Earth. The evolution of global photosynthesis on the Earth brings the global carbon cycle system to an ecological compensation point, i.e. to a stationary state, when the accumulation of hydrocarbons in the earth's crust is completed, and the oxygen concentration in the atmosphere is stabilized.

The key points of the model are confirmed by natural facts based on chemical and isotopic data and interpretation relying on the principle of actualism and modern physico-chemical laws. character, and evolution during geological time has a stepwise progressive character. As a result, climatic cycles and a biotic turnover arise on the Earth. The evolution of global photosynthesis on the Earth brings the global carbon cycle system to an ecological compensation point, i.e. to a stationary state, when the accumulation of hydrocarbons in the earth's crust is completed, and the oxygen concentration in the atmosphere is stabilized.

Completing the work, it should be noted that, of course, the model that underlies the conclusions obtained, of course, is only an approximation to the real description of the system, but the thing is that it makes possible to describe the processes that lead to facts that can be verified (and such independent facts are quite a lot) suggests that the model is a good approximation and can be used as a working tool for further research.

ACKNOWLEDGMENTS

The author expresses his sincere gratitude to Prof. V.I. Petersillie and to Prof. N.M. Prjevalsky for comprehensive support and useful discussion of the work.

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GLOBAL JOURNAL OF HUMAN-SOCIAL SCIENCE: B
GEOGRAPHY, GEO-SCIENCES, ENVIRONMENTAL SCIENCE & DISASTER
MANAGEMENT

Volume 24 Issue 1 Version 1.0 Year 2024

Type: Double Blind Peer Reviewed International Research Journal

Publisher: Global Journals

Online ISSN: 2249-460X & Print ISSN: 0975-587X

Formation, Clashes and Struggles of the Agrarian Extractive and Socio-Environmental Frontiers in the Southwest of Pará

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Abstract- This work proposes to investigate the historical process of formation of the territory, the main actors, the adopted strategies and the clashes between the agrarian extractive frontier and the socio-environmental frontier in the Southwest of Pará. To carry out this work, technical materials were analyzed, such as studies, research and surveys, as well as journalistic articles produced about the region of Southwest Paraense in recent years. As a result of the research, it is observed the formation in the region of a mosaic of protected areas, possible thanks to the coalition of socio-environmentalist movements. There was, however, an agroextractive counter-offensive in the region, based on environmental, agrarian and indigenist deregulation and the dismantling of federal inspection bodies that led to an acceleration of the advance of all the fronts that make up the agrarian extractive frontier.

Keywords: amazon, frontier, extractive cycles, socioenvironmentalism, southwest Pará.

GJHSS-B Classification: FOR Code: 1205



FORMATION CLASHES AND STRUGGLES OF THE AGRARIAN EXTRACTIVE AND SOCIO-ENVIRONMENTAL FRONTIERS IN THE SOUTHWEST OF PARÁ

Strictly as per the compliance and regulations of:



Formation, Clashes and Struggles of the Agrarian Extractive and Socio-Environmental Frontiers in the Southwest of Pará

Formação, Embates e Lutas das Fronteiras Extrativa Agrária e Socioambiental no Sudoeste Paraense

Gabriel M. Domingues ^α & Sérgio Sauer ^σ

Resumo- Este trabalho se propõe a resgatar o processo histórico de formação do território, os principais atores, as estratégias adotadas e os embates entre a fronteira extrativa agrária e a fronteira socioambiental no Sudoeste Paraense. Para realização deste trabalho foram analisados materiais técnicos, tais como estudos, pesquisas e levantamentos, além de matérias jornalísticas produzidas sobre a região do Sudoeste Paraense nos últimos anos. Como resultados da pesquisa, observa-se a formação na região de um mosaico de áreas protegidas, possível graças a coalizão de movimentos socioambientalistas. Observou-se, porém, uma contraofensiva agroextrativa na região, a partir da desregulamentação ambiental, agrária e indigenista e o desmonte dos órgãos de fiscalização federais que ensejaram uma aceleração do avanço de todas as frentes que compõem a fronteira extrativa agrária.

Palavras-chave: *amazônia, fronteira, ciclos extrativos, socioambientalismo, sudoeste paraense.*

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Keywords: *amazon, frontier, extractive cycles, socio-environmentalism, southwest pará.*

1. INTRODUÇÃO

Este trabalho resgata o processo histórico de formação do território, os principais atores, as estratégias adotadas e os embates entre a

fronteira extrativa agrária e a fronteira socioambiental no Sudoeste Paraense. A reflexão utiliza a noção de *fronteira*, uma vez que essa permite abarcar a complexidade de atores, ações e articulações em disputa por um território que, por não estar plenamente estruturado, está sujeito a ser apropriado por diferentes projetos políticos.

O processo histórico de formação do território é promotor de duas concepções distintas de desenvolvimento para a Amazônia brasileira, excludentes entre si e em permanente disputa pelo território. Essas duas concepções se expressam como duas fronteiras, sendo uma extrativa agrária e outra socioambiental.

A fronteira extrativa agrária é formada ao longo do período colonial e avança no sentido de consolidar um modelo de desenvolvimento calcado na concentração de terras, nas desigualdades regionais e na exportação de bens primários. O processo de formação do capitalismo brasileiro reforçou o papel da Amazônia como fronteira agrícola, mineral e energética, à medida que o Estado passou a orientar o processo de integração da região à estrutura econômica do país (Domingues e Sauer, 2021).

Bunker (1984, 1988) explica o subdesenvolvimento da Amazônia a partir da implementação na região de sucessivos modos de extração que, desde o período colonial, impuseram uma dinâmica de exploração intensa do trabalho e da natureza. Tais modos de extração reduziram a capacidade de regeneração dos ecossistemas e impossibilitaram a organização de uma força de trabalho capaz de responder adequadamente às demandas dos novos mercados criados com o advento da sociedade industrial (Bunker, 1984).

A fronteira socioambiental na Amazônia se dá a partir da confluência de três frentes, aqui denominadas de frente ambientalista, indigenista e camponesa. É uma arena política, em processo de disputas e lutas, reunindo um conjunto vasto e diverso de atores, que passam a reivindicar um outro desenvolvimento para a Amazônia. Baseada na defesa da conservação e uso

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sustentável da biodiversidade e no reconhecimento e demarcação dos territórios das comunidades indígenas, extrativistas e demais grupos sociais do campo e das florestas, que tradicionalmente habitam os ambientes amazônicos, a fronteira socioambiental está em constante processo de formulações, reivindicações e enfrentamentos (Hecht, 2014), resultando em conquistas territoriais e novos desafios (Sauer e Castro, 2020), incluindo a resistência à grilagem verde e às propostas neoliberais de mitigação e adaptação à mudança do clima (Borras e Franco, 2018).

O artigo está dividido em três partes. Primeiramente será descrito o processo de formação da fronteira extrativa agrária no Sudoeste Paraense, passando pelos sucessivos ciclos extrativos que se abateram sobre a região, desde o período colonial. De outro lado, será descrita a formação da fronteira socioambiental, possibilitada pela coalizão de diferentes atores e projetos político-institucionais, que ensejaram uma certa contenção do avanço da fronteira extrativa agrária na região.

Será analisada, por fim, a nova investida da fronteira extrativa agrária, a partir do recrudescimento do neoliberalismo na última década, que permitiu a criação de um ambiente político-institucional favorável ao desmantelamento dos avanços conquistados na área socioambiental. O Sudoeste Paraense torna-se, então, palco de disputas políticas e territoriais intensas, tornando incerto dizer qual dos modelos de desenvolvimento prevalecerá nessa região de fronteira.

Este trabalho foi realizado a partir da análise de estudos, pesquisas e levantamentos produzidos sobre a região do Sudoeste Paraense nos últimos anos, combinada com a realização de encontros virtuais com integrantes de órgãos governamentais e outras instituições atuantes nos territórios estudados. Tendo sido realizados em caráter exploratório, essas conversas não foram utilizadas diretamente no texto, mas serviram para orientar o levantamento dos dados empíricos acerca da área de estudo.

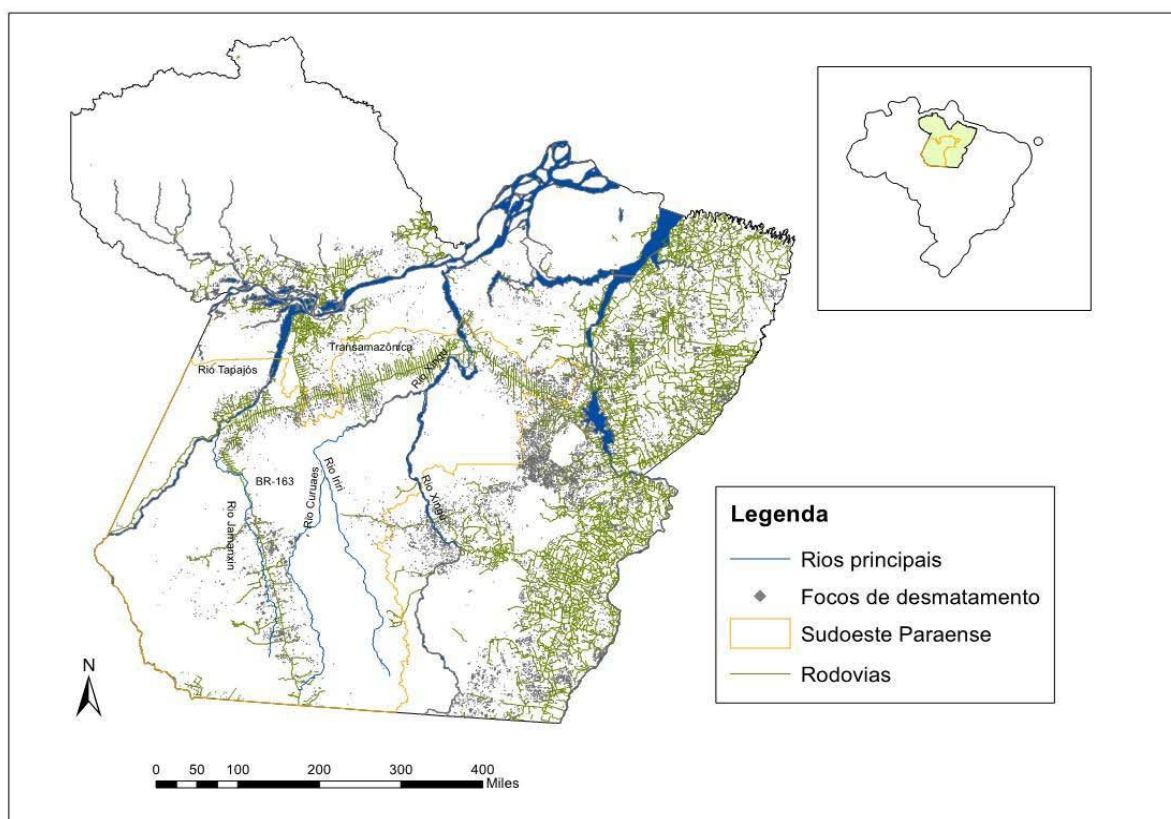
Ao longo de todo o período de realização da pesquisa, foram sendo arquivados artigos e matérias jornalísticas relacionadas ao avanço da fronteira extrativa no Sudoeste Paraense e os seus embates com a fronteira socioambiental. Esse material permitiu a posterior aferição dos fatos relatados durante os encontros virtuais, tendo sido, em parte, citado como referência na construção do texto.

II. OS SUCESSIVOS CICLOS EXTRATIVOS NO SUDOESTE PARAENSE

O Sudoeste Paraense está compreendido entre os vales dos rios Tapajós e Xingu. A região corresponde a uma das seis mesorregiões de planejamento do Estado do Pará, e é composta pelos

municípios de Aveiro, Itaituba, Trairão, Rurópolis, Jacareacanga, Novo Progresso, Altamira, Senador José Porfírio, Anapu, Pacajá, Vitória do Xingu, Brasil Novo, Medicilândia e Uruará (Governo do Pará, 2021).

Sofrendo influência da intersecção das rodovias Cuiabá-Santarém (BR-163) e Transamazônica (BR-230), a região abarca duas das principais frentes de expansão da agropecuária e de pressão sobre o desmatamento e a exploração dos recursos florestais na Amazônia: a frente Cuiabá-Santarém, no eixo da BR-163 e a frente do Iriri, na *Terra do Meio*. Sendo as duas primeiras supridas pelos polos do Norte do Mato Grosso e de Rondônia e a última pelos municípios de São Félix do Xingu e Tucumã (figura 1) (Becker, 2009).



Fonte: elaborado pelo primeiro autor, a partir de dados do Macro ZEE da Amazônia Legal (MMA, 2010).

Figura 1: Sudoeste Paraense: frentes de expansão agropecuária e do desmatamento

Desde o período colonial, cada ciclo extrativo que se sucedia no Sudoeste Paraense provocava um conjunto de rupturas sociais, ecológicas e econômicas que criavam as condições necessárias para o estabelecimento do ciclo extrativo seguinte. Desencadeou-se, assim, os padrões de apropriação da natureza e uso da terra que consolidaram a região como uma fronteira extrativa agrária (Domingues e Sauer, 2021).

A dizimação das populações indígenas da várzea do Amazonas, combinada com a política de descimentos e formação de aldeamentos missionários, durante o ciclo extrativo das *drogas do sertão*,¹ favoreceu a posterior formação dos latifúndios e o aliciamento da mão de obra indígena para as frentes agrícolas e pecuárias, durante o período do Diretório², sob a administração do Marquês de Pombal. A

consolidação dos latifúndios favoreceu, por sua vez, as oligarquias agrárias na política estadual de concessão de terras para a formação dos seringais, durante o ciclo da borracha. O despovoamento das áreas de várzea, provocado pelos ciclos extrativos anteriores, ensejou a política migratória e o estabelecimento do sistema de aviação, com condições extremamente aviltantes para os seringueiros.

A exploração de borracha na Amazônia, iniciada na década de 1850 e alavancada a partir de 1870, chega de forma tardia na região do Sudoeste Paraense, dada a dificuldade de transpor os trechos encachoeirados para acessar os altos cursos dos rios Tapajós e Xingu, e em função da forte resistência apresentada pelos povos indígenas, especialmente no Xingu. Foi somente em 1896, durante a expedição do geógrafo francês Henri Coudreau, que foi confirmada a alta densidade de seringueiras no vale do Xingu. Na ocasião, o pesquisador registrou uma população não-indígena de 804 pessoas vivendo às margens do Xingu e 220 às margens do Iriri (ICMBio, 2015b, Taravella, 2008).

Registra-se a chegada dos primeiros seringueiros às margens do Xingu em 1888. Tratava-se de um grupo de vinte e dois nordestinos que, após cruzarem o rio Fresco, encontraram-se com índios Xipaya e Juruna. Esses últimos, atuando como guias

¹ As chamadas *drogas do sertão* eram substâncias aromáticas com supostos efeitos medicinais e mesmo afrodisíacos, e outras que detinham alto valor de mercado para uso das elites europeias, tais como canela, cravo, anil, cacau, raízes, sementes oleaginosas, salsaparrilha, etc. (Becker e Stenner, 2008).

² O Diretório dos Índios é criado em 1757, em um contexto de ampliação o controle do Estado português sobre o território colonial. As aldeias missionárias são transferidas para o controle da administração leiga, transformando-se em vilas e cidades com toponímias portuguesas. Desdobram-se daí uma série de conflitos com as ordens religiosas que resultará na expulsão dos jesuítas da colônia em 1759 (Malheiro et al., 2021).

dos seringueiros, os teriam impedido de penetrar no território Kayapó, situado mais a oeste. Com a confirmação da alta disponibilidade de seringueiras na região, o fluxo de seringueiros no vale do Xingu foi aumentando vertiginosamente a partir do início do século XX. As estradas construídas no trecho da Volta Grande do Xingu permitiram contornar os trechos encachoeirados para o estabelecimento de *colocações* nas regiões do Médio Xingu, Iriri, Riozinho do Anfrísio e Cururú (Taravella, 2008; ICMBio, 2015b).

Com o fim do primeiro ciclo da borracha, as empresas seringalistas de menor porte continuaram funcionando mesmo após a quebra dos padrões, mantendo ativa a economia da borracha na região. Com o advento do segundo ciclo da borracha, durante a Segunda Guerra Mundial, um novo contingente de migrantes nordestinos é atraído para o vale do Xingu para se alistar no trabalho nos seringais, dando novo impulso ao povoamento da região (ICMBio, 2015a).

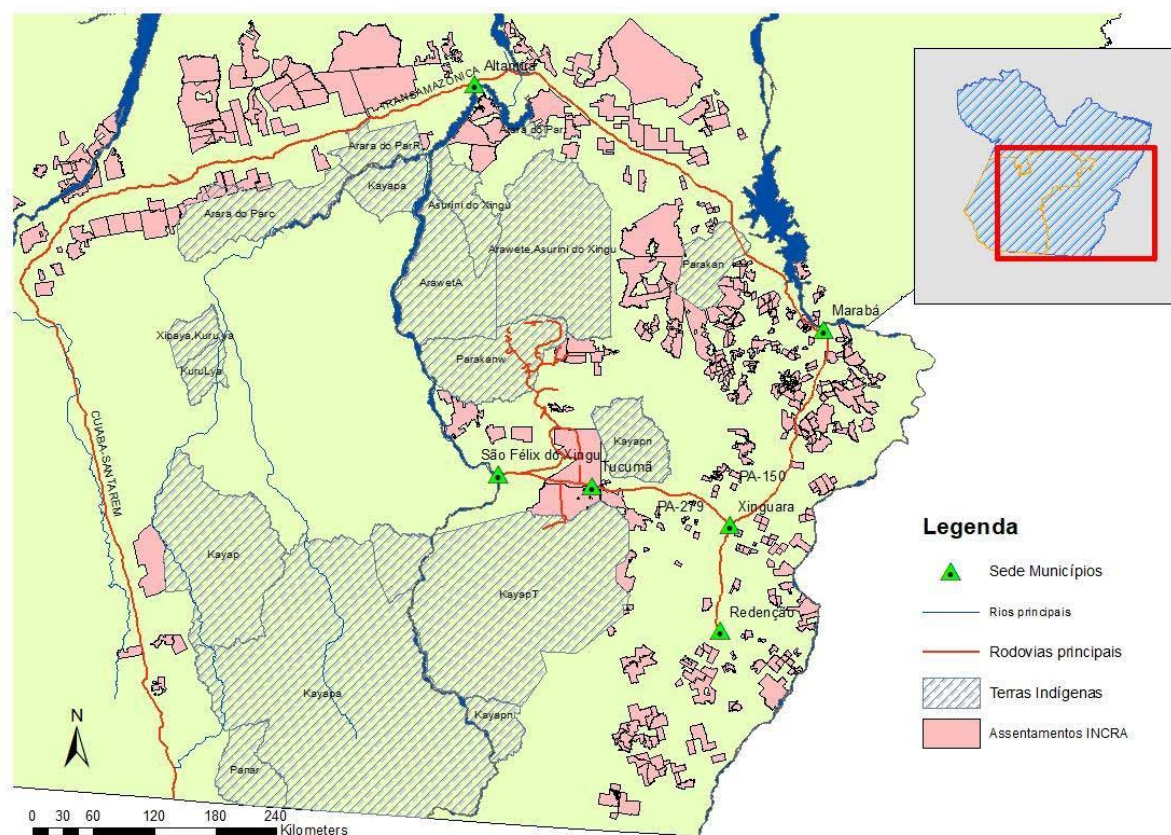
Findada a guerra, com o novo declínio do preço da borracha, os grandes seringalistas foram abandonando as atividades nos seringais. As famílias de seringueiros que haviam se estabelecido nas colocações ao longo do Xingu e seus afluentes mantiveram a coleta do látex até meados da década de 1970, associando-a ao extrativismo da castanha e à agricultura e pesca de subsistência. Entre as décadas de 1950 e 1960 alguns padrões seringalistas passaram a mobilizar as famílias para a caça de animais como ariranhas, lontras, onças e jaguatiricas, cujas peles passariam por uma crescente valorização entre os produtos de exportação (ICMBio, 2010a; ICMBio, 2015a; Villas Bôas, 2012).

No vale do Tapajós, a exploração da borracha se deu em menor escala, dadas as características do solo que não possibilitavam uma ocorrência tão abundante de seringueiras, como as encontradas no Xingu (Hoefle, 2003). Mesmo assim, a região onde hoje está situado município de Itaituba servia como entreposto para trocas comerciais dos produtos que subiam de Santarém e a produção de borracha nos seringais estabelecidos no Alto Tapajós (ICMBio, 2012a). No período da Segunda Guerra Mundial, registra-se o papel do Serviço de Proteção aos Índios (SPI) e da Missão Franciscana na atração dos índios Mundurucu, Kaiabi e Apiaka para a região do rio Cururu, no Alto Tapajós, favorecendo o posterior aliciamento desses índios para o trabalho nos seringais, durante o segundo ciclo da borracha (ICMBio, 2019).

A letargia econômica e a desarticulação social herdadas do ciclo da borracha oportunizaram a caracterização dos vales do Xingu e Tapajós como “vazios demográficos”, propícios à implantação de grandes projetos de infraestrutura pelo Estado, a fim de favorecer agentes privados, ligados ao setor agropecuário. A abertura das rodovias, a partir da

década de 1960, alcança os povos indígenas que haviam se dispersado para as áreas de terra firme, a fim de escapar da escravidão e da morte, durante o período colonial (Bunker, 1988; Oliveira, 2005).

Os conflitos com os indígenas são agravados com a chegada dos migrantes e a implantação dos projetos de assentamento oficiais, que não levaram em conta os aspectos socioecológicos da região. O posterior abandono dos projetos de colonização pelo governo, associado aos incentivos fiscais para o desenvolvimento de projetos agropecuários, favoreceu a eclosão de disputas e conflitos envolvendo colonos, fazendeiros e indígenas, provocando transformações radicais na dinâmica territorial e demográfica da região (Figura 2) (Oliveira, 2005; Torres et al., 2017).



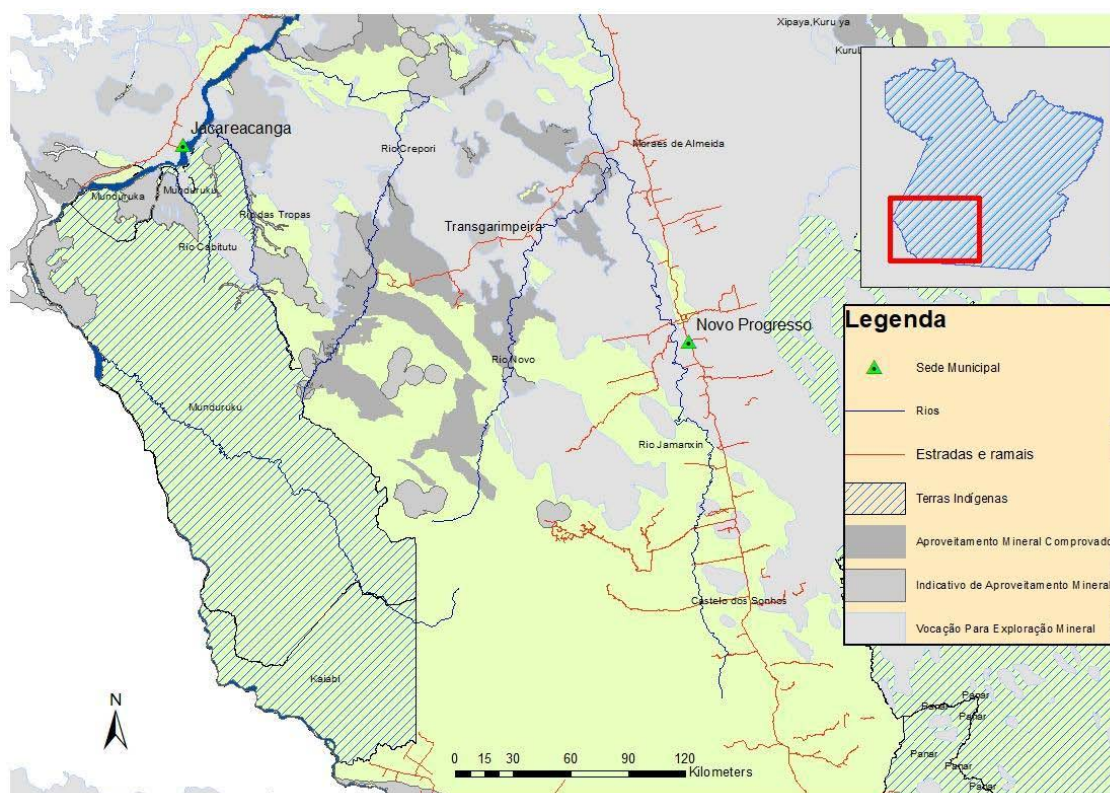
Fonte: elaborado pelo primeiro autor, a partir de dados do MacroZee (MMA, 2010) e INCRA (2020).

Figura 2: Frentes de expansão rodoviária e da colonização, a partir de Marabá

A abertura das rodovias e o apoio insuficiente do Estado aos projetos de assentamento oficiais favoreceram a incursão sobre as jazidas minerais e a formação de um grande contingente de garimpeiros, no Sudoeste Paraense. A atividade garimpeira torna-se uma clara e viável alternativa de renda para aqueles que não conseguiram se estabelecer nos assentamentos do Instituto Nacional de Colonização e Reforma Agrária (INCRA), assim como para diversos outros aventureiros que chegavam aos milhares na região, com a esperança de melhorar de vida a partir da exploração aurífera. Nesse contexto, muitos fazendeiros tornam-se proprietários de garimpo e muitos colonos convertem-se em garimpeiros (Baía Jr., 2014, Oliveira, 2005).

A Reserva Garimpeira do Tapajós é criada em julho de 1983, com uma área de 28.745 km² e abrangendo áreas do Amazonas e do Pará. No mesmo ano é iniciada a construção da rodovia Transgarimpeira, com um traçado de 200 km no sentido oeste, conectando os garimpos situados ao longo dos afluentes do Tapajós à BR-163, a partir do Distrito de Moraes de Almeida (Figura 3). A Transgarimpeira viria ampliar a capacidade de escoamento do ouro extraído nos municípios de Jacareacanga e Itaituba, que até então se dava exclusivamente por via aérea (ICMBIO, 2012). Nesse período os Mundurucu passaram a se

envolver com mais intensidade na exploração aurífera, estabelecendo garimpos na porção leste do seu território, entre os rios Cabitutu, Kaburuá e Tropas (Figura 3) (ICMBio, 2019).



Fonte: elaborado pelo primeiro autor a partir de dados do MacroZee da Amazônia Legal (MMA, 2010).

Figura 3: Expansão da exploração aurífera na bacia do Tapajós

Na bacia do Xingu, é a descoberta da cassiterita em 1976 que provoca um surto de exploração mineral na região. No final da década de 1970, cerca de 14 mil mineiros já tinham se deslocado para tentar a sorte na região de São Félix do Xingu. Diversas pistas de pouso foram abertas e, àquela época, já se observava um tráfego intenso de aeronaves na região, chegando a mais de cinquenta aterrissagens ou decolagens diárias. Em 1979, a empresa Mineração Brasileira de Estanho Ltda. (MIBREL) inicia a extração de cassiterita em uma jazida situada a cerca de cem quilômetros, ao norte de São Félix do Xingu, na localidade que viria a ser conhecida como Vila Taboca. O transporte do material coletado se dava pelo rio Xingu, a partir do Porto Estrela³ (Figura 4) (Taravella, 2008).

Em 1982, a descoberta de uma jazida de ouro nas proximidades de São Félix do Xingu atrai uma caravana de imigrantes que tinham se estabelecido em assentamentos na cidade de Tucumã. No ano seguinte, o prefeito de São Félix do Xingu reúne por conta própria uma equipe de cinquenta trabalhadores para concluir o

trecho final da PA-279, que ligaria o município à rede rodoviária nacional (Taravella, 2008).

³ O Porto Estrela está situado na margem esquerda do Xingu, na altura da estrada que segue para a Vila Taboca, ao norte de São Félix do Xingu (Figura 4).



Fonte: elaborado pelo primeiro autor a partir de dados do MacroZee da Amazônia Legal (MMA, 2010).

Figura 4: Terra do Meio: abertura da estrada da Canopus e da Transiriri

O ciclo da extração mineral serviu para abrir novas estradas e ramais e disponibilizar a mão-de-obra que seria aproveitada pelas empresas madeiras, que começaram a migrar para a região, vindas do Norte do Mato Grosso e do Leste do Pará. A exploração madeireira intensifica a abertura de novas estradas e ramais e abre caminho para o processo de conversão de grandes áreas florestadas em pastagens, o que vem a se tornar o principal mecanismo de apropriação ilegal de terras públicas na região (Torres, 2005; ICMBio, 2010b; Taravella, 2008; ICMBio, 2015a).

Observa-se, então, uma expansão exponencial da pecuária no Sudoeste Paraense entre as décadas de 1980 e 1990. O rebanho bovino salta de pouco mais de 90 mil cabeças na região do Xingu e cerca de 46 mil cabeças na então microrregião do Tapajós (Itaituba e Aveiro), em 1985, para mais de 1,9 milhão na região do Xingu e 538 mil na região Itaituba (Itaituba, Jacareacanga, Aveiro, Rurópolis, Trairão e Novo Progresso) em 2003 (Oliveira, 2005).

Ao sul de Tucumã, o território dos Kayapó é invadido por madeiros e garimpeiros no início da década de 1980. Onde hoje é a TI Kayapó, foi formado o garimpo Maria Bonita, que chegou a ter mais de 10 mil pessoas (Sousa, 2011). Uma licitação para a exploração de madeira nos territórios Kayapó chegou a ser realizada pela Funai, na gestão do então presidente

Romero Jucá, envolvendo a comunidade Kokraimoro. A exploração madeireira e o garimpo são então disseminados entre as comunidades Kayapó, alcançando a área que corresponde hoje à TI Mekrãnotire, onde seria possível contar com a BR-163 para escoamento do material extraído (Figura 2) (ICMBio, 2009).

Como a floresta de mogno estava concentrada às margens dos afluentes do Xingu, é ao longo desses rios que são formados os primeiros assentamentos na região sudeste da *Terra do Meio*. Os pequenos portos construídos nas embocaduras dos rios se tornavam então pontos estratégicos para o transporte da madeira extraída, que era escoada por meio de balsas até São Félix do Xingu (Taravella, 2008).

Após dois ou três anos de intensa exploração madeireira, são esgotados os estoques de mogno nos arredores de São Félix do Xingu, fazendo os madeiros se deslocarem para o norte, em busca de novas áreas de concentração da madeira. Um dos mais conhecidos pioneiros na região foi Alcídio Fontana, que iniciou a abertura de uma estrada a partir do Xingu, na altura do Porto Estrela. Em 1985, sua equipe encontrou com a equipe da mineradora Canopus, que vinha abrindo a estrada a partir da sede da empresa, nas proximidades do Iriri. Com a união das “forças” foi possível concluir rapidamente o traçado da estrada da

Canopus, ligando o Iriri ao Xingu (Figura 4) (Taravella, 2008).

A partir de então, os grupos madeireiros passam a dividir a região da *Terra do Meio* em *áreas de influência*, cada uma variando entre 150 mil e 500 mil hectares, onde cada grupo estaria autorizado a abrir estradas principais e ramais, coletar madeira, abrir clareiras e implantar pistas de pouso, conforme a disponibilidade de mogno observada ao longo dos afluentes do Xingu e do Iriri. Dessa maneira, a exploração madeireira passa a ser realizada na região a partir da autorização do grupo madeireiro que domina a *área de influência*, sob o risco de uso da violência por parte da equipe de campo designada para garantir o domínio dos grupos sobre as respectivas áreas de extração (Taravella, 2008).

Para viabilizar a exploração madeireira na região do rio Iriri e seus afluentes Novo e Carajari, o grupo Maribel liderou, em meados da década de 1980, a abertura da estrada que ficou conhecida como Transiriri, conectando o Iriri à Transamazônica, no município de Uruará e cortando o território dos Arara, que ali haviam se estabelecido. A Transiriri torna-se então um importante ponto de penetração da atividade madeireira, funcionando como um prolongamento de um dos ramais da Transamazônica (Figura 4) (ICMBio, 2010a).

Com o declínio da exploração do mogno, as *áreas de influência* dos grupos madeireiros foram vendidas ou apropriadas pelos grileiros, tornando-se alvos fáceis para a ação de desmatamento e formação de pastagens, tendo em vista a rede de estradas e ramais, as pistas de pouso e toda a infraestrutura preexistente. Os ramais, outrora abertos ao longo dos afluentes do Xingu e do Iriri para escoamento da madeira, são agora convertidos em estradas ao longo das quais são estabelecidas *linha de fazendas*. Por uma questão logística, as áreas de pastagens formadas passam a estar localizadas onde anteriormente havia a maior ocorrência do mogno explorado pelos madeireiros nas antigas *áreas de influência* (Taravella, 2008).

Inaugura-se o ciclo extrativo da terra com a apropriação e grilagem para fins especulativos, e não tanto pelo interesse na exploração dos recursos nela presentes. Nova onda de expropriações se abate sobre as comunidades ribeirinhas e agricultores familiares, que haviam resistido ao fim do ciclo da borracha e à implementação dos projetos agropecuários na região.

Na esteira desse movimento de *pastoralização* da *Terra do Meio*, os fazendeiros se unem para abrir a *estrada nova*, aproveitando o traçado dos antigos ramais madeireiros. A *estrada nova* abre uma conexão direta do coração da *Terra do Meio* à São Félix do Xingu, permitindo um acesso direto à PA-279. Decorre-

se disso uma valorização das terras situadas nas *linhas de fazenda*, o que impulsiona ainda mais o ciclo de grilagem, desmatamento e formação de pastagens (Taravella, 2008).

Assim como ocorrera nos ciclos extrativos anteriores, o ciclo da grilagem-desmatamento-pastagem é favorecido pela degradação ambiental e pelas rupturas nas diferentes formas de organização social promovidas pelo ciclo extrativo precedente. A ausência de sistemas produtivos capazes de manter a circulação de riquezas na região resultou no empobrecimento contínuo e na dispersão da população local. A ausência de controle do território pelo Estado abriu caminho para que, novamente, a floresta, tratada como vazio demográfico, fosse apropriada por agentes externos. Dessa vez, tal apropriação se deu não com o interesse na exploração dos recursos presentes nela, mas visando a sua conversão em áreas de pastagens, cada vez mais valorizadas.

A *pastoralização* de extensas áreas florestais cria as condições para o advento do novo ciclo extrativo que toma conta do Sudoeste Paraense na esteira do recrudescimento da ordem neoliberal global e do *consenso da commodities*⁴, estabelecido para a América Latina e que se abate sobre a Amazônia. A partir do final dos anos de 1990, se estrutura no Estado do Pará o grande complexo produtivo da soja, ganhando impulso a partir de 2001, com a construção do Porto da Cargill, em Santarém. Associada ao asfaltamento parcial da BR-163 pelo Governo Federal, tal estrutura portuária permitiu o escoamento da produção de soja do Mato Grosso pelo sistema fluvial Tapajós-Amazonas⁵ (Sauer e Martins, 2016).

De forma concomitante, ocorre uma reação de atores diversos, resultando na formação da fronteira socioambiental, que, se opondo à fronteira extrativa agrária, passa limitar o seu avanço no Sudoeste Paraense.

III. A REAÇÃO SOCIOAMBIENTALISTA

A visibilidade alcançada pela Aliança dos Povos da Floresta junto ao movimento ambientalista

⁴ Conforme Svampa (2014), o *Consenso das Commodities* é construído sobre a ideia de que há um acordo — tácito ou explícito — sobre o irrevogável ou irresistível caráter da dinâmica extrativa atual, advinda do crescimento da demanda internacional por produtos primários. Tal consenso serve como uma espécie de barreira que deslegitima a resistência coletiva e cerceia a possibilidade de se pensar em outras noções de desenvolvimento, para além dos projetos extrativos voltados para a exportação.

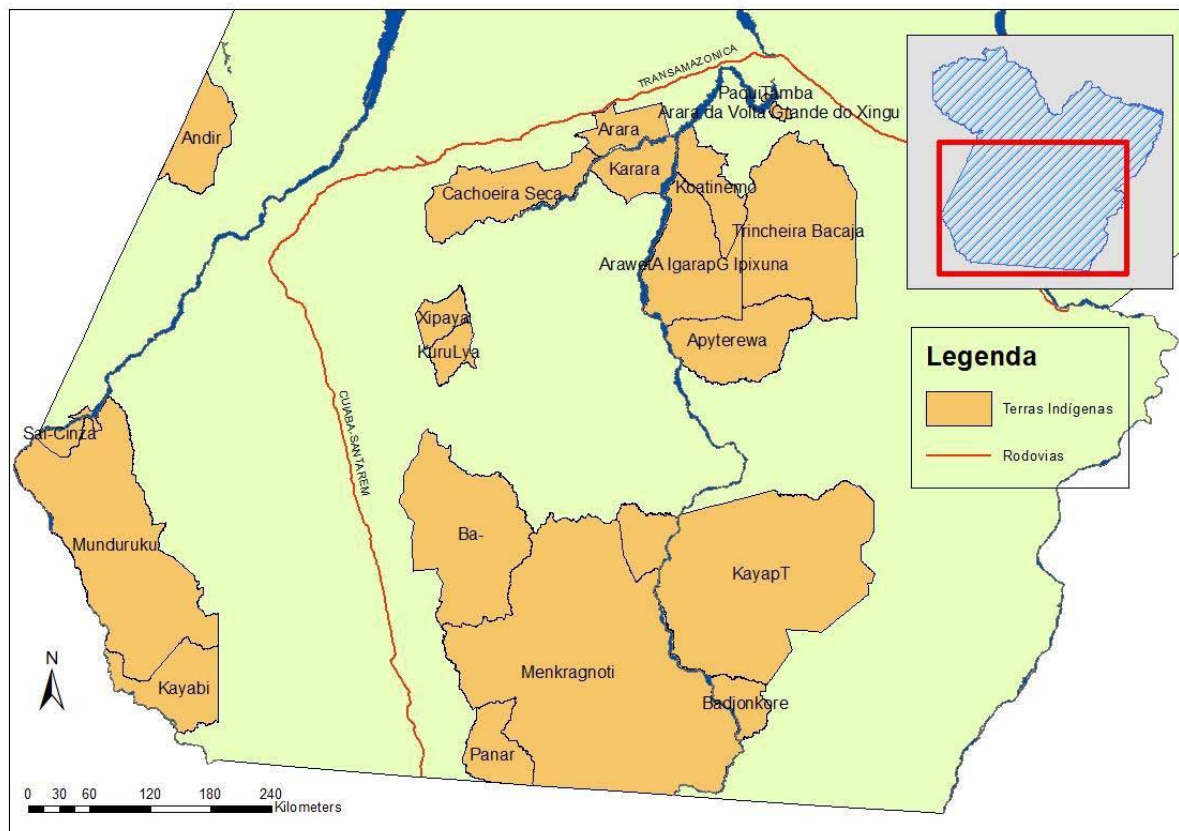
⁵ De acordo com dados da Conab (2016), a produção de soja no Estado do Pará salta de 2,6 mil toneladas, na safra 2000/01, para mais de 200 mil toneladas na safra 2004/05, ultrapassando um milhão de toneladas na safra de 2014/15. Em extensão de área cultivada, representou um crescimento passando de menos de 10 mil hectares, na safra 2000/01, para cerca de 70 mil hectares na safra de 2004/05, saltando para cerca 340 mil hectares na safra 2014/15 (Sauer e Martins, 2016).

internacional, associada à ampla repercussão do assassinato de Chico Mendes, somam-se aos avanços nos direitos socioambientais da constituição de 1988, criando um cenário favorável à definição de espaços territoriais especialmente protegidos pelo Estado. Os temas da proteção da biodiversidade e dos direitos dos povos indígenas, das comunidades extrativistas e dos demais povos e comunidades tradicionais ganham destaque nesse contexto.

Com a alternância dos ciclos da exploração mineral, madeireira e pecuária no Pará, amplia-se a expropriação e os conflitos com os povos originários, que passam a contar, cada vez mais, com o apoio de diversas ONGs nacionais e internacionais. Aumentou

significativamente, especialmente a partir dos anos 1990, a pressão sobre o governo brasileiro para a demarcação e defesa das terras indígenas e criação de unidades de conservação ambiental.

No Sudeste Paraense, foram homologadas, em 1991, as TIs Parakanã, Kayapó e Xicrin do Cateté, formando um primeiro bloco de contenção da expansão da fronteira extrativa agrária que avançava a partir do eixo da Belém-Brasília. No mesmo ano foram homologadas no Sudoeste Paraense a TI Paquicamba (povo Yudjá), na volta grande do Xingu, a TI Arara, nas proximidades da Transamazônica e a TI Sai Cinza (povo Mundurukú), na bacia do Tapajós (Figura 5) (ISA, 2011a).



Fonte: elaborado pelo primeiro autor, a partir de dados do MacroZee da Amazônia Legal (MMA, 2010).

Figura 5: Terras Indígenas no Sudoeste Paraense

Em 1993 foi homologada a TI Menkragnoti (povo Kayapó) e, em 1996 foi homologado o bloco formado pela TI Araweté/Igarapé Ipixuna (povo Araweté), pela TI Koatimeno (povo Asurini do Xingu) e pela TI Trincheira Bacajá (povo Kayapó). Em 1998 é homologada a TI 203 Kararaô (povo Kayapó), fechando a sequência das TIs homologadas na década de 1990 (Quadro 1) (ISA, 2011a).

O processo de declaração, demarcação e homologação das Terras Indígenas não transcorreu sem conflitos no Sudoeste Paraense. Em muitos casos, os conflitos dos indígenas com fazendeiros, madeireiros e garimpeiros é acirrado pela ação ambígua do Estado,

que acaba favorecendo o assentamento de famílias de pequenos agricultores nos territórios indígenas, gerando elementos adicionais de complexidade na disputa por terras na região (Figura 2).

O abandono, pelo governo brasileiro, dos projetos de colonização ao longo da rodovia Transamazônica provocou uma forte mobilização social na região. Contando com o apoio da Comissão Pastoral da Terra (CPT), organizações diversas, tais como sindicatos dos trabalhadores rurais, associações de pequenos produtores e movimentos de mulheres e da juventude, se articulam no intuito de resistir às expulsões e ao abandono da terra e passam a

reivindicar do Estado a garantia de condições mínimas de sobrevivência, produção e reprodução das comunidades rurais, na região da Transamazônica (MPST, 1999).

Quadro 1: Homologação das Terras Indígenas no Sudoeste Paraense

Terra Indígena	Etnia	Homologação
Andirá-Marau	Sateré Mawé	Dec.93.069 de 06/08/1986
Paquiçamba	yudjá	Dec 388 de 24/12/1991
Arara	Arara	Dec.399 de 24/12/1991
Kayapó	Kayapó	Dec 316 de 29/10/1991
Parakanã	Parakanã	Dec.248 de 29/10/1991
Sai Cinza	Munduruku	Dec.393 de 24/12/1991
Menkragnoti	Kayapó	Dec.s/n de 19/08 1993
Araweté/Igarapé Ipixuna	Araweté	Dec.s/n de 05/01/1996
Koatimeno	Asurini do Xingu	Dec s/n de 05/01/1996
Trincheira/Bacajá	Kayapó	Dec.s/n de 02/10/1996
Kararaô	Kayapó	Dec.s/n de 14/04/1998
Kayabi	Apiaká, Kaiabi, Munduruku	Posse indígena em 2002. Decreto 25/04/2013
Mundurucu	Apiaká, Munduruku	Dec. s/n 25/02/2004
Kuruáya	Kuruaya	Dec. s/n de 18/04/2006
Xipaya	Xipaya	Posse indígena em 2006. Decreto s/n06/06/2012
Apyterewa	Parakanã	Dec.s/n de 19/04/2007
Cachoeira Seca do Iriri	Arara	Posse indígena em 2008. Decreto s/n 05/04/2016
Baú	Kayapó	Dec.s/n de 19/06/2008
Panará	Panará	Dec. s/n de 18/04/2008
Arara da Volta Grande do Xingu	Arara	Posse indígena em 2008. Decreto S/n 20/04/2015

Fonte: ISA (2011a).

Em 1987, é criado o Movimento Pela Sobrevivência da Transamazônica (MPST), com o lema Viver, Produzir e Preservar, que se torna uma articulação regional das lutas. São realizadas então um conjunto de atos, públicos, protestos, caravanas, greves e passeatas em prol da melhoria das condições de vida dos trabalhadores rurais na região (MPST, 1999).

Defendendo melhoria das condições de vida dos colonos nas áreas de educação, saúde, infraestrutura urbana, transporte, segurança e apoio à produção agrícola, o movimento realiza, em 1991, uma marcha até Brasília, a fim de levar suas reivindicações à Presidência da República. No mesmo ano, é criada a Fundação Viver, Produzir e Preservar (FVPP), que, sediada em Altamira, torna-se a figura jurídica do movimento (Taravella, 2008; FVPP, 2021).

Em meados da década de 1990, após a realização da Eco-92 e o início dos desembolsos do PP-G7⁶ para a implementação dos Projetos Demonstrativos Ambientais⁷, a FVPP torna-se um

parceiro local privilegiado para a realização de projetos-piloto voltados ao incentivo de atividades produtivas florestais que pudessem ser apresentadas como alternativas ao desmatamento. Nesse contexto, o movimento dos trabalhadores rurais da Transamazônica se aproxima cada vez mais da temática da preservação ambiental e a FVPP vai se afirmando como uma referência do movimento socioambiental regional⁸ (Taravella, 2008).

Em 1998, o MPST muda sua denominação para Movimento pelo Desenvolvimento da Transamazônica e Xingu (MDTX), entendendo que o movimento entrava naquele momento em um outro patamar de lutas e reivindicações voltadas para a formulação de propostas de desenvolvimento (FVPP, 2021). O MDTX, passa então a congregar 113 entidades da região da Transamazônica e do Xingu (MDTX, 2001b).

voltadas para o uso e conservação da biodiversidade, por meio de Projetos Demonstrativos Ambientais (PDA). Entre 1995 e 1998, com apoio do PP-G7, foram demarcadas 58 terras indígenas, ou 26 milhões de hectares, e outras 115 foram reconhecidas. Em 1994 foram criadas oito reservas extrativistas na Amazônia (Becker, 2009).

⁸ A partir de 2000, com o lançamento do Programa de Desenvolvimento Socioambiental de Produção Familiar Rural da Amazônia (Proambiente), a FVPP se tornou referência para implementação de projetos demonstrativos na região da Transamazônica. O Proambiente previa pagamento por serviços ambientais a agricultores familiares que se dispusessem a realizar a transição para sistemas de produção sustentáveis (MMA, 2006).

⁶ O Programa Piloto para Proteção das Florestas Tropicais Brasileiras (PP-G7) era financiado pelos países da (União Europeia e Canadá, França, Alemanha, Itália, Japão, Estados Unidos e Reino Unido) e administrado pelo Banco Mundial.

⁷ Lançado oficialmente em 1993 e iniciado em 1994, o PP-G7 passou a canalizar recursos para a criação e implementação de áreas protegidas na Amazônia, bem como para o apoio a iniciativas

Em agosto de 1999, na esteira da realização do Grito da Amazônia, realizado em 1993, e do primeiro Grito da Terra Brasil⁹, em 1995, a Federação dos Trabalhadores na Agricultura do Pará (FETAGRI-PA) em parceria com a Fetagri Regional, a FVPP, a CPT/Xingu e os Movimentos e Organizações Urbanas, realizaram o *Grita Transamazônica*, com o lema *Asfaltamento Já*. Assumindo os impactos no solo e na biodiversidade, causados pelo modelo de agricultura que vinha se praticando nos assentamentos da Transamazônica, a pauta do *Grita Transamazônica* incluiu também um componente voltado à política ambiental, onde se propunha uma nova dinâmica produtiva para a agricultura familiar (MPST, 1999).

Sob a justificativa do avanço das grandes madeiras na região, foram propostas duas áreas de proteção ambiental: o Parque Nacional do Iriri, à margem esquerda da Rodovia Transamazônica, envolvendo os municípios de Altamira, Brasil Novo, Rurópolis, Trairão e Novo Progresso; e a Floresta Nacional da Transamazônica, localizada ao Norte da rodovia, após o limite da área oficial de colonização, até a margem direita do rio Amazonas¹⁰. O componente indígena do *Grita Transamazônica* rejeitava a construção do Complexo Hidrelétrico do Xingu, pedia a imediata desintrusão da Terra Indígena Cachoeira Seca/Iriri, a instalação de postos de vigilância para coibir o avanço da extração ilegal de madeira, a demarcação da Terra Indígena Kuruaya, a identificação da Terra Indígena Xipaya, a demarcação das Florestas Nacionais do Xingu e Altamira e a criação de uma área de desenvolvimento sustentável na região da *Terra do Meio*, entre os rios Xingu e Iriri, para impedir a invasão desenfreada de madeireiros vindos de São Félix do Xingu e da Santarém-Cuiabá (MPST, 1999).

A região do interflúvio Xingu-Iriri, ficou conhecida nas décadas de 1990 e 2000 como a *Terra do Meio*, durante as campanhas de repercussão internacional empreendidas pelo *Greenpeace* contra a extração ilegal de mogno. Cercada por terras indígenas e abrangendo porções dos municípios de Altamira e São Félix do Xingu (figura 6), a região da *Terra do Meio* se destacou no passado pela produção de látex, tornando-se mais recentemente uma das áreas prioritárias para a conservação da sociobiodiversidade, inserindo-se no corredor de diversidade socioambiental do Xingu¹¹ e para a contenção das frentes de

desmatamento que atingem as áreas de influência das rodovias Transamazônica e Cuiabá-Santarém (Taravella, 2008; ICMBio, 2010a; Villas-Bôas, 2012).

⁹ Os movimentos conhecidos como *Gritos* fazem parte de uma etapa de mobilização dos trabalhadores rurais brasileiros na década de 1990 em torno de pautas unificadas em que os diversos segmentos da população rural e urbana se reúnem e realizam negociações conjuntas junto ao Poder Público (MPST, 1999).

¹⁰ Ao Norte da Transamazônica seria criada, mais tarde, a Reserva Extrativista Verde Para Sempre e ao Sul seria estabelecido o mosaico de áreas protegidas da *Terra do Meio*.

¹¹ O corredor de diversidade socioambiental do Xingu é abrangido por 20 terras indígenas e 10 unidades de conservação, estendendo-se por mais de 28 milhões de hectares, estando situado entre os estados

do Mato Grosso e Pará e entre os biomas Cerrado e Amazônia (Villas-Bôas, 2012).





Ministério do Meio Ambiente contrata o Instituto Socioambiental (ISA¹²) para a realização de um estudo técnico para a criação de um mosaico de unidades de conservação na *Terra do Meio*. O estudo foi desenvolvido em parceria com Instituto de Pesquisa Ambiental da Amazônia¹³ (Ipam), FVPP, CPT, Instituto

Em 2002, com o governo federal pressionado a dar resposta em relação aos eventos ocorridos na região da *Terra do Meio* e da Transamazônica, o

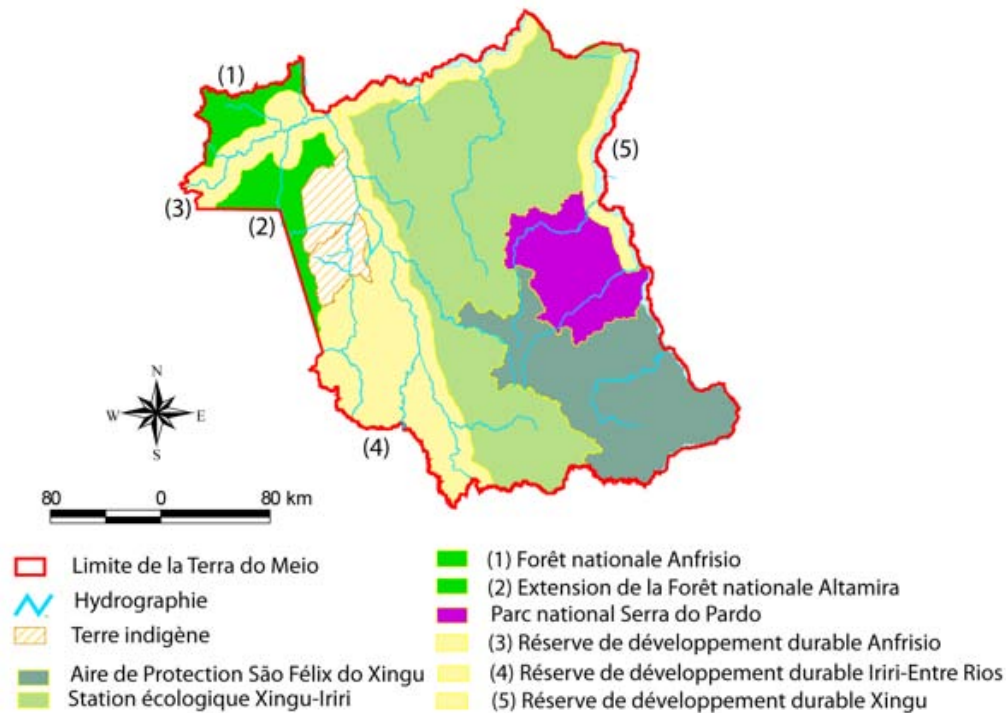
do Homem e Meio Ambiente da Amazônia¹⁴ (Imazon), Greenpeace, CIMI e USP. Outras instituições também participaram do processo, tais como Secretaria de Coordenação da Amazônia do Ministério do Meio Ambiente (SCA/MMA), Conservation International (CI), The Nature Conservancy (TNC), Secretaria de Ciência, Tecnologia e Meio Ambiente do Estado do Pará (SECTAM), Universidade Federal do Pará (UFPA), Museu Paraense Emílio Goeldi (MPEG) e Federação dos Trabalhadores Rurais Agricultores e Agricultoras do Estado do Pará (Fetagri) (Taravella, 2008; ICMBio, 2015b).

O relatório final é lançado em 2003, apresentando a primeira proposta para o mosaico de áreas protegidas da *Terra do Meio*, que serviu de base para a sua posterior implementação pelo governo (Figuras 7 e 8).

No estudo coordenado pelo ISA, a região do riozinho do Anfrísio ganha especial destaque, sendo indicada como prioritária para a criação de uma área protegida, dada a densidade de famílias ribeirinhas

vivendo na área, bem como as ameaças por elas sofridas, advindas da ação de madeireiros e grileiros. A partir de então, diversas organizações regionais, tais como o MDTX, a FVPP, o GTA e a CPT passam a se articular em torno da viabilização do projeto de criação da Reserva Extrativista do Riozinho do Anfrísio (Taravella, 2008).

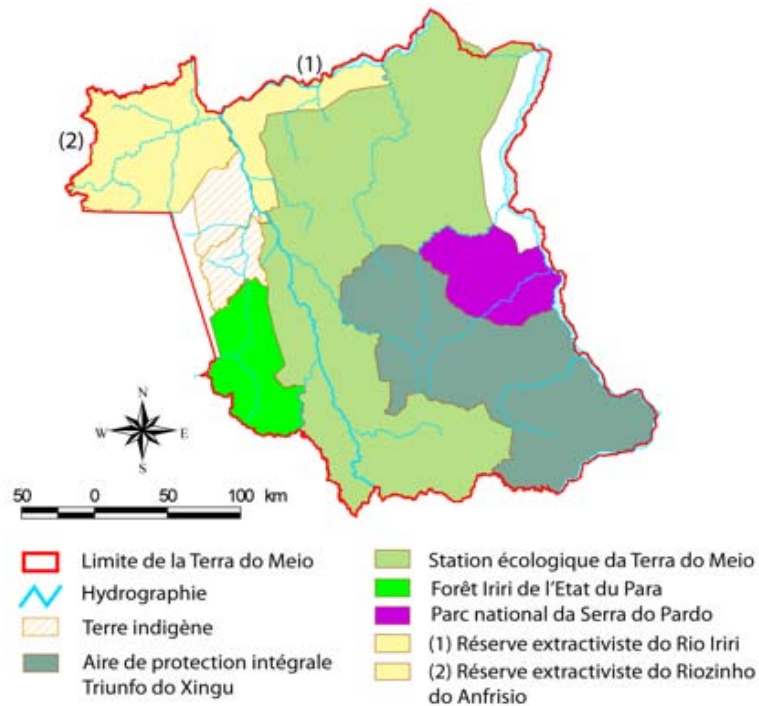
Paralelamente à mobilização que ocorria para a criação das áreas protegidas na *Terra do Meio*, diversas organizações da sociedade civil e movimentos sociais se mobilizavam desde 2001 no Oeste do Pará, motivados pela construção do Porto da Cargill, em Santarém, e pela promessa de asfaltamento da BR-163. Temia-se uma nova onda de desmatamento provocado pela valorização das terras na região, acompanhada de processos de grilagem de terras públicas, migração desordenada, conflitos fundiários, assassinato de lideranças sindicais e degradação das condições de vida da população, tal como já havia sido observado na região nas décadas anteriores (ISA et al., 2003; Schittini, 2010; Sauer e Martins, 2016).



Fonte: Taravella (2008, p.457).

Figura 7: Mosaico de áreas protegidas da Terra do Meio proposto pelo ISA

¹⁴ O Imazon foi criado em 1990 pelo ecólogo americano Christofer Uhl e os colegas Adalberto Veríssimo, David McGrath e Paulo Barreto. Uhl era vinculado à Embrapa e à ONG americana Woods Hole Research Center (WHRC). Alarmado com as imagens do desmatamento da floresta amazônica, no final da década de 1980, Uhl decide fundar uma organização que pudesse diminuir a defasagem de informações relacionadas às profundas transformações observadas na paisagem amazônica (Taravella, 2008; Imazon, 2021).



Fonte: Taravella (2008, p.457).

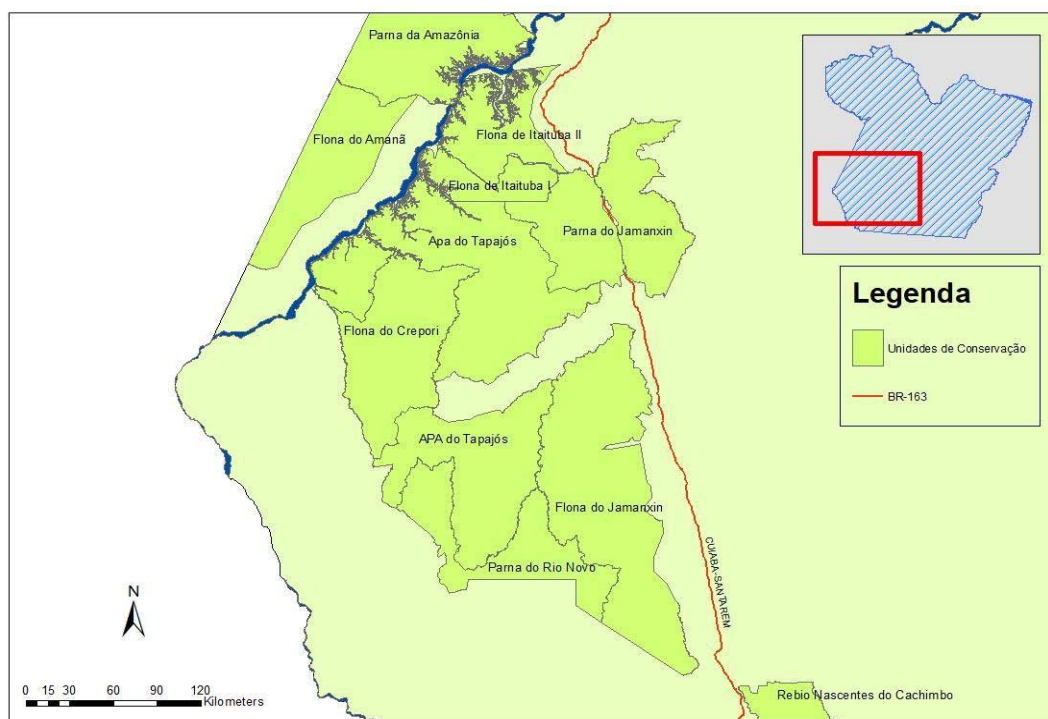
Figura 8: Mosaico da Terra do Meio como foi implementado

Em outubro de 2003, a FVPP, juntamente com a Fetagri Pará, promoveu uma conferência popular regional com o tema “Desenvolvimento do Território da Transamazônica, Xingu e Cuiabá-Santarém” agregando as (já históricas) demandas dos movimentos sociais da Transamazônica o pleito trazido pelas organizações atuantes na área de influência da BR-163, que passam a se articular por meio do Fórum dos Movimentos Sociais da BR-163. Nessa conferência foi apresentada uma proposta de Plano de Desenvolvimento Territorial Integrado e Sustentável para a Transamazônica e o Xingu (FVPP, 2003; Schittini, 2010). Após a conferência de Altamira, ocorreram outros três eventos regionais e populares, organizados pelas entidades ligadas ao Fórum dos Movimentos Sociais da BR-163, reivindicando a adoção de um modelo de desenvolvimento sustentável para a região situada na área de influência da BR-163.

Esses encontros serviram para fortalecer a articulação e a mobilização das organizações ligadas à temática socioambiental atuantes na região. Foram apresentadas aos órgãos das três esferas do governo e à sociedade em geral, propostas voltadas ao ordenamento fundiário, com a criação de áreas protegidas e projetos de assentamentos em áreas florestais; ao apoio às atividades produtivas de base familiar, melhoria dos serviços públicos, em especial nas áreas de saúde, educação e saneamento; fortalecimento e apoio às organizações sociais da região e o combate à impunidade e à violência no campo (Fetagri-BAM et al., 2003).

Em resposta à mobilização da sociedade civil, o governo federal lança em fevereiro de 2004, o documento base do Plano de Desenvolvimento Regional Sustentável para a Área de Influência da BR-163 com ações organizadas dentro de quatro eixos: ordenamento territorial e gestão ambiental; fomento a atividades produtivas sustentáveis; infraestrutura para o desenvolvimento; inclusão social e cidadania. O plano incluía no eixo de ordenamento territorial e gestão ambiental a criação e consolidação de unidades de conservação e a regularização e proteção de terras indígenas na área de influência da rodovia (Schittini, 2010). No mesmo ano, a *Terra do Meio* e a área de influência da BR-163 foram incluídas no Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia Legal (PPCDAM), tornando o processo de criação e implementação de áreas protegidas nessas áreas passíveis de serem financiadas pelo Programa de Áreas Protegidas da Amazônia (ARPA) (Taravella, 2008).

No dia 12 de fevereiro de 2005 ocorre o assassinato da missionária norte-americana Dorothy Stang, a Irmã Dorothy, que atuava junto à CPT em favor dos direitos das famílias assentadas na região da Transamazônica, mais especificamente no município de Anapu (PA). A ampla repercussão nacional e internacional do assassinato precipitou a criação da Estação Ecológica da Terra do Meio e do Parque Nacional da Serra do Pardo, na *Terra do Meio* (Figura 8), cujos decretos de criação foram assinados pelo presidente Lula no dia 17 de fevereiro de 2005 (Taravella, 2008; Schittini, 2010; ICMBio, 2015b).



Fonte: elaborado pelo primeiro autor a partir de dados do MacroZee da Amazônia Legal (MMA, 2010).

Figura 9: Criação das Unidades de Conservação ao longo do eixo da BR-163

Acompanhando a criação das unidades de conservação da *Terra do Meio*, foram criadas outras unidades de conservação em áreas consideradas estratégicas para contenção do avanço da fronteira agropecuária na Amazônia. Foi publicado o decreto s/n de 13 de fevereiro de 2005, destinando mais de 6 milhões de hectares a unidades de conservação. Nesse ato foram criadas a APA Tapajós, as Flonas Amanã, Trairão, Crepori e Jamanxin e os Parques Nacionais do Jamanxin e Rio Novo, além de ter sido expandido o Parque Nacional da Amazônia (figura 9). De forma alinhada com os princípios do PPCDAM, o critério para a criação das unidades de conservação na área de influência da BR-163 não se baseou apenas na conservação da biodiversidade, mas também na criação de um *cinturão verde* para dificultar o avanço do desmatamento ilegal ao longo do eixo da rodovia, afastando as expectativas de regularização fundiária futura e desestimulando a grilagem de terras na região (Schittini, 2010).

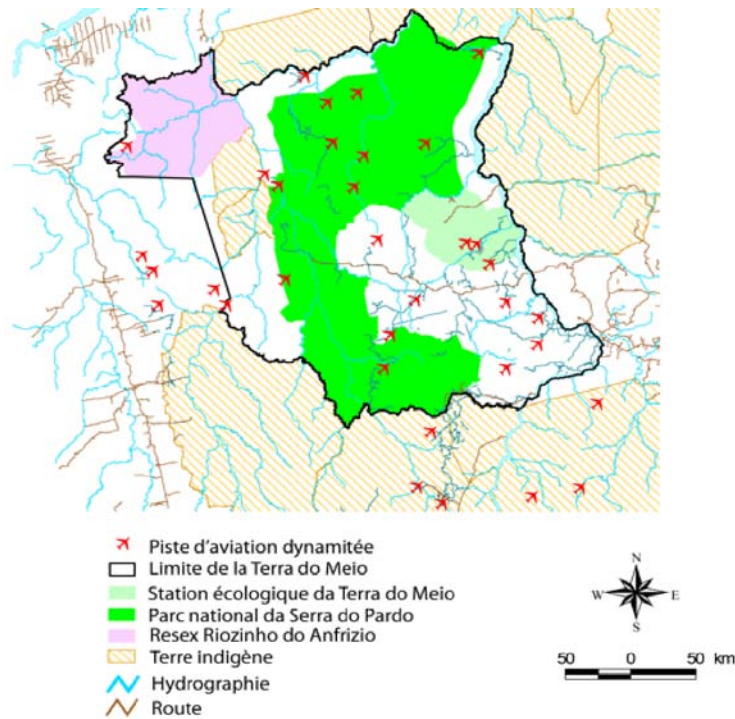
Em fevereiro de 2006 é deflagrada uma operação do Ibama para destruição de trinta e quatro pistas de pouso clandestinas, sendo dez delas situadas na estação ecológica (Figura 10). Na operação foram empregados mais de quinhentos quilos de dinamites, utilizados para tornar a região inacessível aos aviões. Em dezembro do mesmo ano, ocorre a operação Monte Pardo, dedicada à fiscalização de desmatamentos localizados especificamente na área do Parque Nacional da Serra do Pardo (TARAVELLA, 2008). Na esteira dessas operações, o governo federal

decretava, em junho de 2006, a criação da Resex do Rio Iriri e em dezembro do mesmo ano o Estado do Pará decretava a criação da APA Triunfo do Xingu¹⁵ e da Floresta Estadual do Iriri (Figura 8) (ICMBIO, 2015b).

Em 2006 ocorre também a formação da Rede Terra do Meio, constituída pelo conjunto das organizações socioambientalistas e os órgãos oficiais atuantes na região. Com a criação da Resex do Rio Iriri e da APA do Triunfo do Xingu, as atenções se voltam para a área da Resex do Rio Xingu, que permanecia desprotegida e tinha sido alvo de invasões de quatro fazendas, entre os anos de 2002 e 2005, com prejuízo para as famílias ribeirinhas que passaram a sofrer ameaças constantes de pistoleiros a serviços dos fazendeiros interessados em se apropriar das áreas tradicionalmente ocupadas¹⁶. Intensificam-se as mobilizações a favor da criação da Resex Rio Xingu (ICMBio, 2012b).

¹⁵ Conforme os estudos preliminares, a APA Trinfo do Xingu foi concebida como uma área de 1.347.000 hectares. O governo do Pará acabou criando a APA com 1.670.000 hectares, beneficiando os proprietários de terras que teriam suas propriedades inseridas na Esec *Terra do Meio* (Figuras 7 e 8) (Costa, 2013).

¹⁶ Em 2005, após a primeira solicitação de criação de uma área protegida, o Ibama recebeu documentos de protesto da Indústria, Comércio, Exportação e Navegação do Xingu Ltda (Incexil), reclamando a propriedade de áreas localizadas dentro da proposta de criação da Resex. No mesmo período o órgão ambiental recebeu um manifesto de repúdio, assinado pelos prefeitos da região (com exceção de Pacajá e Medicilândia), contra a criação das Resex Verde Pra Sempre e Riozinho do Anfrísio, da Esec da Terra do Meio e do Parna Serra do Pardo (ICMBio, 2012b).

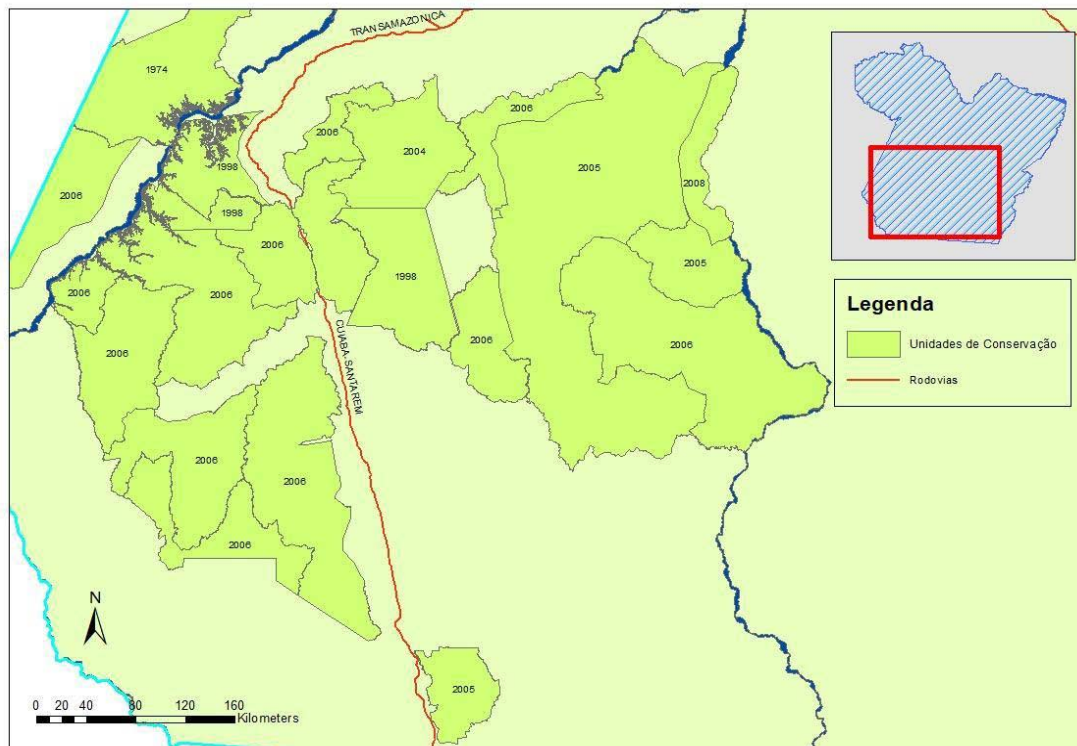


Fonte: Taravella (2008, p.516).

Figura 10: Localização das pistas de pouso dinamitadas na Terra do Meio

Em 2006 e 2008 ocorreram os dois primeiros encontros da Rede Terra do Meio demandando a criação urgente da Resex de criação da Resex do Rio Xingu. No início de 2008 foi organizada a última de uma série de viagens de lideranças locais a Brasília para

pressionar as autoridades em favor da criação da Resex. Finalmente, em junho de 2008, é decretada a criação da Resex do Rio Xingu, concluindo o processo de criação das unidades de conservação do Sudoeste Paraense (Figura 11) (ICMBio, 2012b).

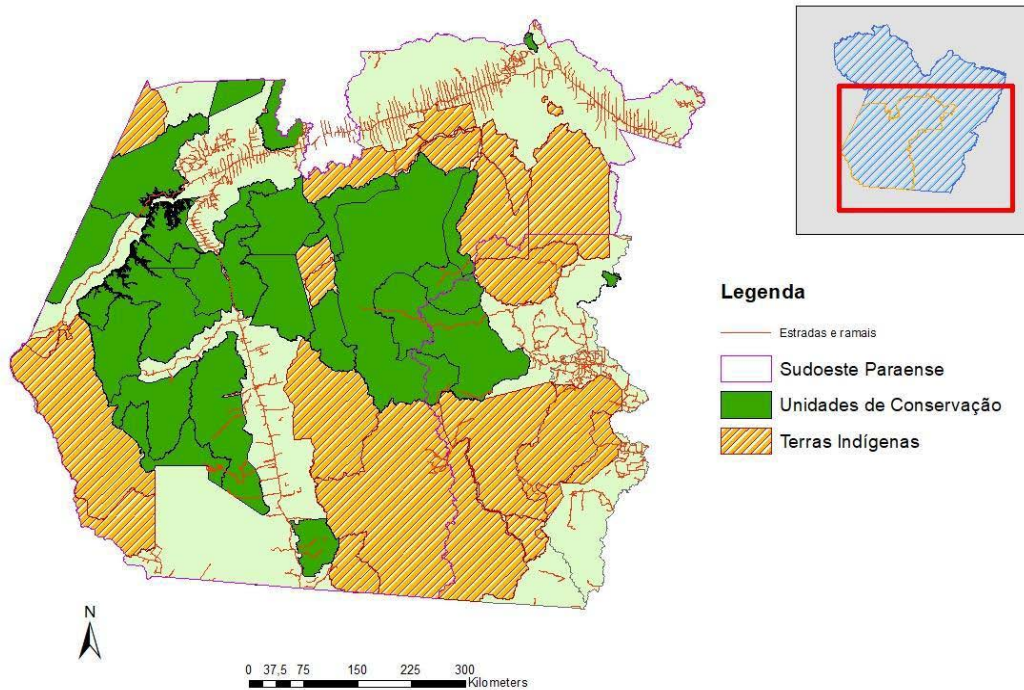


Fonte: elaborado pelo primeiro autor a partir de dados do MacroZee da Amazônia Legal (MMA, 2010).

Figura 11: Ano de criação das unidades de conservação no Sudoeste Paraense

Na região do Sudoeste Paraense existem atualmente quinze unidades de conservação federais, ocupando um total de mais de 15,63 milhões de hectares, sendo seis unidades de proteção integral (Parques Nacionais do Rio Novo, Jamanxin, Amazônia e Rio Novo, Reserva Biológica Nascentes Serra do Cahimbo e Estação Ecológica Terra do Meio, somando, 6,62 milhões de hectares) e nove unidades de uso sustentável (Flonas Jamanxin, Itaituba I, Itaituba II, Trairão, Tapajós, Crepori, Amaná e Altamira, Resex Tapajós-Arapiuns, Riozinho do Anfrísio e Rio Iriri e APA

do Tapajós, somando 9 milhões de hectares) (ICMBIO, 2021). Regista-se na região a presença de diversas etnias indígenas como os Munduruku, Sateré Mawé, Kaiabi, Kayapó, Asurini, Arara e Araweté, distribuídas em 21 Terras Indígenas, somando cerca de 17,13 milhões de hectares. Destaque para a TI Menkragnoti, com quase 5 milhões de hectares e a TI Munduruku, com cerca de 2,38 milhões de hectares. Quatorze TIs encontram-se regularizadas e as demais ainda em fase de homologação (Figura 12) (Funai, 2019).



Fonte: elaborado pelo primeiro autor, a partir de dados do MacroZee Amazônia da Amazônia Legal (MMA, 2010).

Figura 12: Sudoeste Paraense: Unidades de Conservação e Terras Indígenas

Dessa maneira, o mosaico de áreas protegidas que se forma no Sudoeste Paraense (figura 12) assume essa função principal de contenção da expansão dessas frentes de expansão da fronteira extrativa agrária na região.

IV. EMBATES COM A FRONTEIRA EXTRATIVA AGRÁRIA

A partir da segunda metade da década de 2000, a criação das áreas protegidas provocou uma transformação na dinâmica de apropriação de terras, ocupação do território, exploração dos recursos naturais e desmatamento no Sudoeste Paraense. Em contrapartida, os agentes da fronteira extrativa agrária se reorganizaram rapidamente, a fim de dar continuidade ao processo de acumulação extrativa, mesmo após a destinação das áreas públicas para a formação de um mosaico de áreas protegidas na região.

A criação da Estação Ecológica da Terra do Meio freou o acelerado processo de apropriação de terras por meio da formação de pastagens, que se expandia a partir de São Félix do Xingu. Diante da impossibilidade de aquisição futura de direitos sobre a terra, os fazendeiros passaram a reorientar o esforço de ocupação de terras para as áreas ainda não afetadas pelas unidades de conservação federais (Taravella, 2008).

A criação da Resex do Riozinho do Anfrísio, da Flona Trairão e do Parna Jamanxin pôs fim às pretensões das quadrilhas de grilagem que disputavam as terras públicas na área correspondente à Gleba Leite¹⁷ (Figura 13), uma das áreas mais disputadas do oeste paraense. Uma vez que a criação unidades de

¹⁷ Torres et al (2017), com base em informações da Operação Faroeste, da Polícia Federal de 2004, relata a participação do INCRA na apropriação ilegal de terras públicas (grilagem), com a emissão de certidões avalizando posses ilegais.

Observa-se um novo impulso para o estabelecimento de grupos madeireiros na região que, a exemplo do que ocorrera anteriormente na região da *Terra do Meio*, passaram a delimitar suas áreas de influência, havendo, por vezes, conflitos e disputas pelo controle de áreas específicas. O Projeto de Assentamento Areia torna-se um centro de coordenação, controle e distribuição das toras extraídas nas áreas da Resex do Riozinho do Anfrísio, do Parna Jamanxin e da Flona Trairão. As toras são encaminhadas para as serrarias do município de Trairão e a madeira beneficiada segue para Miritituba, onde estão as sedes das principais madeireiras, que providenciam o transporte do material pela via fluvial (Figura 14) (TORRES et al., 2017).



The map illustrates the study area in the Transamazônica region. Key locations and features include:

- Geographical Features:** Rio Tapajós, Transamazônica, Itaituba, Miritituba, Trairão, PA Areia, RESEX RIOZINHO DO ANFRÍSIO, FLONA DO TRAIÃO, and PARQUE NACIONAL DO JAMAXIM.
- Infrastructure:** BR-163.
- Numbered Locations:** Four numbered circles (1, 2, 3, 4) indicate specific study sites. Circle 1 is located near the RESEX RIOZINHO DO ANFRÍSIO. Circle 2 is located near PA Areia. Circle 3 is located near Trairão. Circle 4 is located near Miritituba.
- Scale:** A scale bar at the bottom right indicates distances from 0 to 40 Km.
- North Arrow:** A north arrow is located in the top right corner.

Figura 14: Esquema logístico do roubo de madeira das UCs na região de Trairão

De toda maneira, observa-se uma tendência de queda na taxa de desmatamento na região da *Terra do Meio*, a partir de 2007, com uma estabilização entre os anos de 2001 e 2013 e uma nova tendência de alta, a partir de 2014¹⁸. Entre os anos de 2011 e 2014 registra-se um aumento vertiginoso da extração de madeira ilegal e da abertura de estradas e ramais abertos em áreas sensíveis para a conservação como a Terra Indígena Cachoeira Seca e a Resex do Riozinho do Anfrísio (Doblas, 2015, ICMBio, 2010a).

Na região da BR-163, o asfaltamento da rodovia, a transferência da etapa de cria de bezerros de outros locais e o aumento do preço da arroba do boi concorreram para inflacionar o mercado de terras na região de Novo Progresso e Castelo dos Sonhos, impulsionando o processo de apropriação e valorização das terras por meio do desmatamento e formação de pastagem, na década de 2010¹⁹. Contribuiu para esse processo a sensação de impunidade gerada pelos processos de regularização fundiárias de áreas outrora griladas, levados a cabo no âmbito do Programa Terra Legal²⁰. Soma-se a isso a capitalização dos comerciantes de Novo Progresso, propiciada pelo aumento vertiginoso do tráfego da caminhões graneleiros na BR-163, que impulsionou o investimento na pecuária e no desmatamento²¹ (Torres et al., 2017).

A partir da eleição de Jair Bolsonaro à presidência da república, em outubro de 2018, observa-se uma aceleração do avanço de todas as frentes que compõem a fronteira extrativa agrária. Antes mesmo de tomar posse, o discurso do presidente eleito de criminalização dos movimentos sociais do campo, ataques a ONGs ambientalistas e órgãos de fiscalização ambiental e sua promessa de extinguir o Ministério do Meio Ambiente, foi suficiente para provocar uma onda de invasões de terras indígenas e unidades de conservação, queimadas e desmatamento ilegal, mortes e violência em diversas regiões da fronteira amazônica²² (De Olho nos Ruralistas, 2018; Ferreira, 2018; Ribas, 2018).

¹⁸ Dados do PRODES/INPE mostram uma redução de cerca 500km² desmatados em 2007, para cerca de 100km² desmatados em 2011 na região da *Terra do Meio* (Doblas, 2015).

¹⁹ Nesse processo, um hectare de floresta podia saltar de R\$350,00 para R\$5.000, após desmate e implantação do pasto (Torres et al., 2017).

²⁰ O Programa Terra Legal foi lançado em 2009, baseado na MP 458/2009 e na Lei nº 11.952/2009, com o objetivo de acelerar a regularização de até trezentos mil ocupações informais em terras públicas da Amazônia Legal, em 463 municípios (Brasil, 2009).

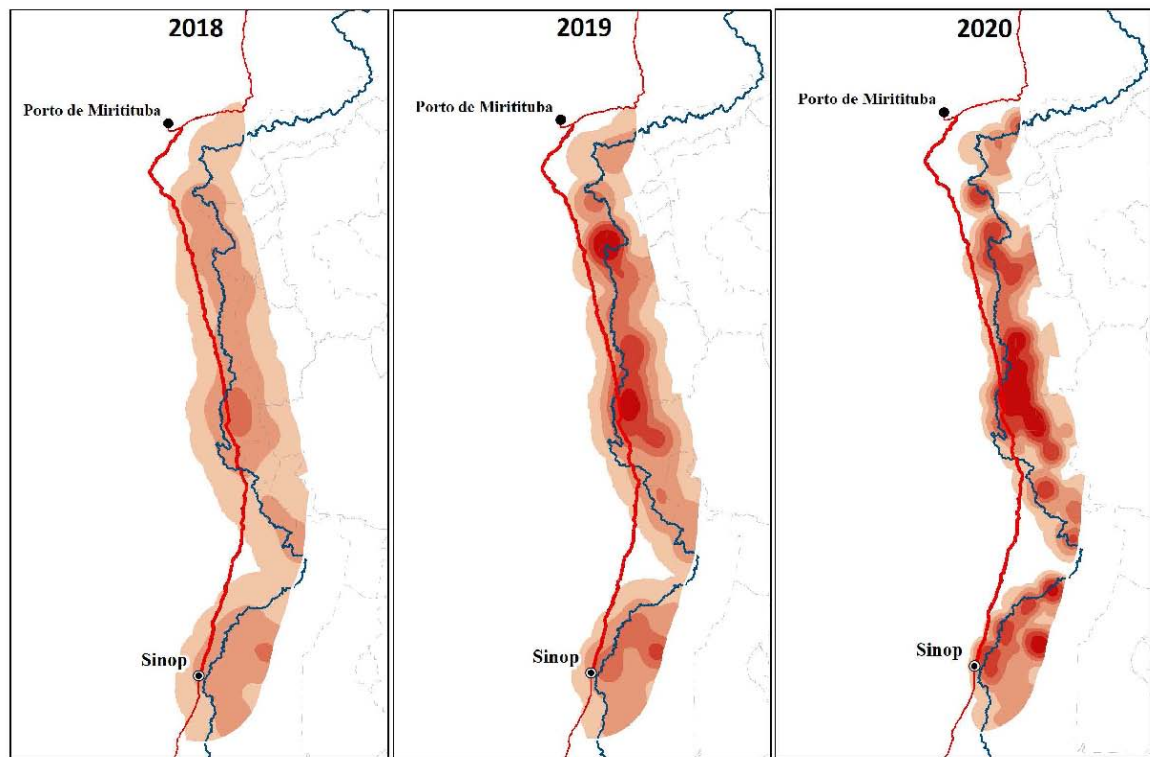
²¹ Torres et al. (2017) afirmam que a infraestrutura, da soja capitalizava indiretamente o desmatamento, em regiões onde o plantio do grão não se expandiria. Fecha-se assim mais um ciclo extrativo iniciado com o capital acumulado da atividade madeireira na década anterior, que passa a ser reinvestido na produção de grãos (Oliveira, 2005), que por sua vez ensejará a abertura de novas áreas para pastagens e para a própria extração de madeira.

²² Já em novembro de 2018, o sistema de alerta de desmatamento do Instituto Imazon, indicava um aumento de 406% no desmatamento da

No Sudoeste Paraense, entre os anos de 2018 e 2020, houve um avanço do desmatamento em duas frentes principais: a partir de Novo Progresso e de São Félix do Xingu (Figura 1). O que ameaça a conectividade do Corredor de Biodiversidade do Xingu, por meio da possibilidade de conexão dessas duas frentes. Houve uma explosão do processo de grilagem de terras, garimpo ilegal e extração de madeira dentro das áreas protegidas (Rede Xingu+, 2020a).

Entre os anos de 2019 e 2020, com a conclusão da pavimentação da BR-163, no trecho entre Sinop (MT) e Miritituba (PA), observa-se o aumento do desmatamento ao longo desse trecho da rodovia, em especial na sua margem direita, tendo havido um aumento de 40% na taxa de desmatamento em 2019, em relação ao ano anterior, e um aumento de 58% em 2020 em relação a 2019, que já tinha sido um ano de aumento intenso do desmatamento (Figura 15). Tudo isso em um cenário em que persiste a falta de regularização fundiária, agravando-se a grilagem de terras.

Amazônia em relação ao mesmo período do ano anterior (Imazon, 2018).



Fonte: Rede Xingu+ (2020a, p.13).

Figura 15: Evolução da densidade do desmatamento no trecho Sinop-Miritituba da BR-163, entre os anos de 2018 e 2020

No dia 10 agosto de 2019 ocorreu o episódio que ficou conhecido como o “dia do fogo”, em que produtores rurais do Pará promoveram uma ação orquestrada para incendiar extensas áreas de floresta, a fim de chamar atenção do presidente da república para a necessidade de se desmatar, para que haja a produção. A ação planejada dos produtores foi revelada a partir de conversas em redes sociais de um produtor de Novo Progresso que foram interceptadas pela Polícia Federal. O dia do fogo abrangeu áreas de Novo Progresso, Altamira e São Félix do Xingu, atingindo, em especial a Flona do Jamanxin, a Rebio Nacentes da Serra do Cachimbo e a APA Triunfo do Xingu (Machado, 2019; Camargos, 2020).

No final de semana dos dias 9 e 11 de agosto, os satélites do INPE detectaram 431 focos de incêndio em Altamira, representando 39% dos focos de incêndio registrados em todo o Brasil e uma alta de 179% em relação aos dias anteriores. Em Novo Progresso foram registrados 124 focos de incêndio, aumento de 300% em relação ao dia anterior. São Félix do Xingu apresentou 288 focos de incêndio entre os dias 9 e 11 de agosto, representando um aumento de 329% em relação aos três dias anteriores. Somente na APA Triunfo do Xingu foram perdidos 3.000 hectares de floresta no período²³.

Na bacia do Xingu, estima-se que entre 2018 e 2020 tenham sido desmatados 1.200 km² no interior de unidades de conservação e 660 km² no interior de terras indígenas (Cowie, 2021). A partir de 2020, o advento da pandemia de Covid-19, associado ao aumento do preço do ouro no mercado internacional e às restrições a operações de vigilância e repressão aos ilícitos por parte do Estado, provocou o aumento do desmatamento por garimpo nas terras indígenas, seguido do aumento do número de casos de ocorrência e morte por Covid-19 nessas áreas (Rede Xingu+, 2020b).

Somente em 2020, a TI Munduruku perdeu mais de 2 mil hectares de floresta para o garimpo ilegal. Em 2021 as terras indígenas Munduruku e Sai Cinza foram alvo de uma grande operação contra o garimpo ilegal, envolvendo agentes da Polícia Federal, Exército, Força Nacional e Ibama. Em retaliação, os garimpeiros invadiram a aldeia e incendiaram a casa de Maria Leuse Munduruku, uma das principais lideranças locais, que faz oposição ao garimpo no território Munduruku²⁴.

²³ Em função de desentendimentos entre as polícias Civil e Federal e dos vínculos dos suspeitos com integrantes da bancada ruralista no Congresso Nacional, as investigações sobre o dia do fogo não prosperaram, sendo suspensas sem que tenha havido nenhum indiciado (Camargos, 2021).

²⁴ Adonias Munduruku foi apontado como o responsável pelo ataque. Ele foi um dos sete munduruku que embarcaram em um voo da FAB de Jacareacanga para Brasília em agosto de 2021. Na ocasião, o MPF abriu investigação sobre a conduta do então ministro do meio ambiente, Ricardo Salles, que havia se encontrado com garimpeiros

(Folha, 2021; Gussen, 2021). Na cidade de Jacareacanga, manifestantes pró-garimpo tentaram invadir a base da Polícia Federal e depredar aeronaves e equipamentos policiais. No confronto entre os manifestantes e agentes da PF, dez garimpeiros ficaram feridos (Modelli, 2021; Carneiro, 2021).

As Terras Indígenas Apyterewa, Cachoeira Seca, Ituna-Itatá e Trincheira Bacajá²⁵ passaram a figurar no topo do ranking das mais desmatadas da Amazônia em 2020. As operações do Ibama realizadas nessas áreas entre novembro de 2019 e abril 2020 estavam logrando sucesso na redução do desmatamento. O cancelamento, porém, de forma injustificada das ações de fiscalização do Ibama, seguida da exoneração dos fiscais responsáveis, fez o desmatamento explodir nessas terras indígenas, a partir de maio de 2020 (Rede Xingu+, 2020a).

Os coordenadores da operação do Ibama foram exonerados duas semanas após a operação realizada para combater o garimpo ilegal na Amazônia, em abril de 2020. No início do mesmo mês o diretor de Proteção Ambiental do Ibama, Olivaldi Azevedo, já tinha sido exonerado, após matéria veiculada no programa Fantástico, sobre a ação de garimpeiros ilegais no Pará e a convivência dos órgãos federais (Rede Xingu+, 2020a).

As invasões na TI Trincheira Bacajá alcançaram em agosto de 2019 a alarmante taxa de 1.115 hectares desmatados, a maior taxa mensal de desmatamento desde a sua homologação, em 1996. Na ocasião, um grupo de invasores ameaçou de morte as lideranças Xikrin, dizendo que iriam “caçar os índios”. Nesse período foi reativado um ramal saindo das TI's Apyterewa e Araweté/Igarapé Ipixuna, entrando 40 km pra dentro do território Xikrin (Rede Xingu+, 2020a). As invasões são impulsionadas pela expectativa de regularização das terras griladas, pelos discursos das autoridades públicas a favor da redução das terras indígenas e à inoperância dos órgãos federais responsáveis pela fiscalização (Rede Xingu+, 2020a).

As unidades de conservação também vêm sofrendo com o recrudescimento da fronteira extrativa. Na Resex Riozinho do Anfrísio foi registrada, entre 2018 e 2020, a abertura de mais de 366 km de estradas ilegais, para viabilizar a retirada e o escoamento de

madeira. Além da intensificação do roubo da madeira, a Resex assistiu à reativação do garimpo Fortaleza, fechado desde 2004. O garimpo foi reaberto em 2018 e teve em 2019 a atividade intensificada com o uso de maquinário pesado. O retorno dos garimpos ilegais também foi registrado na Resex do Rio Iriri, no Parna Serra do Pardo e na Flona de Altamira. Moradores do Parque Nacional relataram que os invasores espalhavam boatos de que a área não estava mais protegida, que o ICMBio e o Ibama não funcionavam mais e que o garimpo tinha sido legalizado (Rede Xingu+, 2020a; 2020b).

Nas duas APAs estaduais a devastação acelerou vertiginosamente entre 2018 e 2020. A APA Triunfo do Xingu perdeu mais de 93 mil hectares de floresta no período, consolidando-se como a unidade de conservação mais desmatada do Brasil. O desmatamento é motivado, em especial pelo processo de especulação fundiária. Em 2019, foi registrado um desmatamento de mais de 9 mil hectares em apenas um mês, em função das expectativas criadas com o sancionamento da nova lei agrária do Pará (Lei 8.878/2019), que favorece a regularização das áreas anteriormente griladas (Rede Xingu+, 2020a).

Na Floresta Estadual do Iriri foi detectada em 2018 a abertura de uma pista de pouso e de uma estrada vinda da Esec da Terra do Meio. Em agosto de 2020 essa estrada foi finalizada e reativada, interconectando as duas UCs. A Fes do Iriri é fruto da cobiça de ambas as frentes de desmatamento: a que vem de Novo Progresso, na área de influência da BR-163, e a que vem de São Félix do Xingu. Em 2020 foram encontrados 201 imóveis cadastrados no Cadastro Ambiental Rural (CAR) dentro da floresta estadual, correspondendo a 90% do seu território e indicando um esquema de ocupação irregular de terras, por meio do loteamento virtual da UC (Rede Xingu+, 2020a).

V. CONSIDERAÇÕES FINAIS

Este trabalho se propôs a analisar os embates entre a fronteira extrativa agrária e a fronteira socioambiental no Sudoeste Paraense, colocando em perspectiva, de um lado, os sucessivos ciclos extrativos sofridos pela região, desde o período colonial e, de outro, a coalização de diferentes atores e projetos político-institucionais, que forçaram um novo ordenamento do território e possibilitaram, em certa medida, a contenção do avanço da fronteira extrativa agrária na região. Desde o período colonial, cada ciclo extrativo que se sucedia no Sudoeste Paraense provocava um conjunto de rupturas sociais, ecológicas e econômicas que criavam as condições necessárias para o estabelecimento do ciclo extrativo seguinte. Desencadeou-se, assim, os padrões de apropriação da natureza e uso da terra que consolidaram a região como uma fronteira extrativa agrária.

em Jacareacanga e atuado de forma a prejudicar a operação de combate ao garimpo ilegal dentro das terras indígenas Mundurucu e Sai Cinza, no Vale do Tapajós. Além de ter ordenado a paralisação temporária da operação, Salles teria solicitado aeronave da FAB para levar para Brasília um grupo de moradores envolvidos com o garimpo nas terras indígenas, a fim de que reunissem com o próprio ministro e outras autoridades do governo federal, tendo em vista a legalização do garimpo em terras indígenas (G1, 2020; Folha, 2021).

²⁵ Em agosto de 2020, veio a falecer, em decorrência das complicações causadas pela Covid-19, o cacique Beptok Kaiapó Xikrin, de 78 anos, líder histórico da aldeia Pyatko, conhecido como o cacique Onça. Se tratou da primeira vítima indígena do novo coronavírus na região do médio Xingu (Galvani, 2020).

Antes que toda a floresta fosse convertida em pastagem, e que os territórios sucumbissem à fúria do garimpo e da extração madeireira, movimentos sociais formados por colonos, ribeirinhos e indígenas, com o apoio da Comissão Pastoral da Terra e do Conselho Indigenista Missionário, passaram a se organizar, reivindicando do Estado a implementação de um novo modelo de desenvolvimento para a região, voltado para a consolidação dos assentamentos e a melhoria das condições de vida das comunidades rurais.

Um novo modelo produtivo passou a ser buscado, tendo em vista a redução dos impactos da agricultura no solo e na biodiversidade. Uma política de ordenamento do território era exigida, de forma a proteger os povos indígenas e comunidades extrativistas e garantir a manutenção das áreas florestadas, frente o avanço da fronteira extrativa. A aliança com as grandes organizações ambientalistas internacionais, tais como Greenpeace, CI, TNC e WWF deu projeção internacional às demandas presentes nos territórios e aumentaram a pressão sobre o governo federal para que fossem criadas áreas protegidas que garantissem a proteção da diversidade biológica e cultural da região.

A instituição das áreas protegidas abriu caminho para que financiamentos de fontes diversas, tais como Banco Mundial, PP-G7, ARPA, Fundo Amazônia, fundações e organizações internacionais, viabilizassem projetos, desenvolvidos nos territórios por atores diversos, voltados para a gestão ambiental e territorial, o desenvolvimento de cadeias produtivas de base florestal, o fortalecimento da organização social e produtiva, e a valorização dos saberes e práticas tradicionais. O Sudoeste Paraense consolida-se, assim, enquanto uma fronteira socioambiental.

A região torna-se então um território em disputa pelos agentes da fronteira extrativa agrária e da fronteira socioambiental. A contradição se dá a partir do momento em que as atividades extrativas avançam, com a convivência e apoio do Estado, sobre as áreas protegidas, criadas pelo próprio Estado, justamente para conter esse avanço. Com a deposição da presidente Dilma Rousseff e a posterior eleição de Jair Bolsonaro à presidência da república, ocorre uma desregulamentação ambiental e agrária e um desmonte dos órgãos de fiscalização, ensejando uma aceleração do avanço de todas as frentes que compõem a fronteira extrativa. Explode o garimpo, o roubo de madeira, a grilagem de terras, bem como o desmatamento associado a essas atividades, no interior das terras indígenas e das unidades de conservação, colocando em risco as populações que vivem nesses territórios e descredibilizando o projeto conservacionista que um dia foi proposto quando essas áreas foram institucionalizadas.

Diante da necessidade de cerrar fileiras contra a aceleração do avanço da fronteira extrativa, a

tendência é que sejam atenuados os tensionamentos existentes no interior da fronteira socioambiental, provocados pelos interesses divergentes dos atores que atuam na escala dos territórios e dos que atuam nas escalas nacional e global. Estabelece-se uma queda de braço entre o avanço contínuo das atividades extrativas sobre os territórios e a defesa das áreas florestadas, independente dos fins almejados para elas. Além do mais, a fronteira socioambiental busca se consolidar não somente como uma resistência ao avanço da fronteira extrativa agrária, mas também como uma proposta alternativa de desenvolvimento para a região, com foco no aproveitamento econômico da biodiversidade e no fortalecimento dos territórios, a partir de uma perspectiva comunitária.

Fica claro o papel do Estado no sentido de definir o modelo de desenvolvimento a ser priorizado e dispor dos instrumentos legais e dos recursos necessários para a sua implementação. A simples entrega da região ao sabor das flutuações da dinâmica da fronteira significará o predomínio definitivo da lógica extrativa, pois é ela que rege a atual fase da economia globalizada.

AGRADECIMENTOS

As pesquisas e os trabalhos de tese no Programa de Doutorado do Centro de Desenvolvimento Sustentável (CDS) da Universidade de Brasília (UnB) foram possíveis graças ao apoio do Ministério do Meio Ambiente (MMA) e da Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Código de Financiamento 001, Brasil.

A orientação da tese no Centro de Desenvolvimento Sustentável (CDS) foi apoiada pelo Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) com bolsa de pesquisa (bolsa produtividade em pesquisa) para Sérgio Sauer.

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GLOBAL JOURNAL OF HUMAN-SOCIAL SCIENCE: B
GEOGRAPHY, GEO-SCIENCES, ENVIRONMENTAL SCIENCE & DISASTER
MANAGEMENT

Volume 24 Issue 1 Version 1.0 Year 2024

Type: Double Blind Peer Reviewed International Research Journal

Publisher: Global Journals

Online ISSN: 2249-460X & Print ISSN: 0975-587X

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GJHSS-B Classification: LCC: HE5623



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Cultivating Campus Mobility: An In-Depth Analysis of Student Perspectives on the Bulldog Transit System at Alabama A&M University

Imoro Nuhu Yahaya ^α & Jacob Oluwoye ^σ

Abstract- This research provides an overview of the transportation system at Alabama A&M University (AAMU) and discusses the Bulldog Transit System (BTS), which operates on campus to facilitate student and staff mobility. The study is being conducted to assess the perspective of AAMU students regarding the performance of the BTS on campus and how it affects their transportation experience. The research questions aim to understand the main transport mode of students, how students perceive the efficiency and effectiveness of the BTS operations, what service(s) students need the BTS to improve in its operation, and the relationship between students' BTS efficiency rating and drivers' behaviors/conducts. The study reviewed literature on the importance of public transport, factors that positively influence mode of choice, and the decrease in public transport ridership and a significant shift to private transport and other transport modes. The researcher employed quantitative research methods to collect and analyze data. Simple random sampling was used to distribute questionnaires to undergraduate and graduate students of a university. Statistical Package for Social Sciences (SPSS) and Excel were used to analyze the data. The findings show that most respondents were young adults in their first year of college or pursuing graduate-level studies. Also, on-campus students prefer walking over using the bus system to campus. Off-campus students prefer private means due to lack of reliability in public transport. First-year students usually walked to campus, while higher academic levels such as master's and doctorate students tended to prefer using private vehicles. Students prioritize fast movement and convenience in selecting their transport mode. They want management to develop an app to track buses and provide reliable off-campus services. Students view the BTS system favorably and agree that drivers have excellent communication and driving skills though they barely patronize it. The standardized predictor errors were high suggesting that the data or the simple regression model used in the analysis may not be sufficient representation of accurate predictions. Further research can explore the reasons behind the positive perception despite low BTS usage, safety of pedestrians and cyclists on campus, and environmental impacts of transportation. Alternative modeling techniques such as multiple regression models could be used in future research to minimize predictor errors. Incorporating these findings into planning and policy-making processes can lead to more effective and user-centric transportation solutions for the campus.

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I. GENERAL INTRODUCTION

a) Introduction

According to the Alabama Agricultural and Mechanical University (AAMU) Campus Master Plan (CMP) of 2014, the Alabama A&M University campus is bounded approximately by Moore Mill Road to the east, Chase Road and J.F. Drake State Technical College to the south, Memorial Parkway to the west, and Industrial Drive to the north.

AAMU secured over 2 million dollars grant from the Federal Transit Authority (FTA) which was used to improve the University's transportation system by creating new parking, re-striping, identify lots, controlled access gates and shuttle service (AAMU CMP, 2014). This aimed at ensuring that people are safe and to reduce accidents on campus (AAMU CMP 2014).

The Bulldog Transit System (BTS) is owned by AAMU Transport Department. Its objective is to make students movement life easier by busing them around the university beautiful campus (AAMU Transport Department Website). The BTS has 15 Bus stops, 8 Bus Stops with Shelter and 1 Transfer Station dotted across campus and residential halls (AAMU Transit Map). The BTS operates five days a week from 7:30am to 10:30pm on Monday through Thursday and 7:30am to 6:30pm on Fridays (AAMU MP 2014). Its movement is scheduled every 15 minutes at each of the bus stops (AAMU MP 2014). The BTS provides special service to the mall and Wal-Mart on Friday afternoon. A research study is being conducted to assess the perspective of AAMU students regarding the performance of the BTS on campus and how it affects their transportation experience.

The noteworthy discoveries of this research will have great importance for campus transportation planning and policy-making. The findings will support universities to design campus transportation systems that are not only efficient but also tailored to the needs and preferences of the campus community. Furthermore, it can have a considerable impact on decisions regarding the enhancement of public transportation services on campus.

b) Literature Review

Public transport should be encouraged to promote sustainable transport system – they should have a high quality service to attract and satisfy a wide

range of passengers (Aydin *et al.*, 2021). Kim and Shaban (2016) conducted research into the influence of bus service satisfaction on university students' mode of choice and revealed that three factors such as bus stop service, bus service, and bus drivers services positively influences mode of choice. They concluded that bus stops that have air condition provide little space that cannot accommodate more than five students on the bench. This makes waiting for bus at the station difficult during summer time when temperature is over 40°C. The students opt for other alternatives instead of using the bus. University students have a low satisfaction level towards the bus service due to the bad quality of facilities of the buses and bus stations (Hasimah *et al.*, 2021). There has been a decrease in public transport ridership and a significant shift to private transport and other transport modes (Erik & Matej, 2020; Abdallah *et al.*, 2020). Many people use a family car as their predominant source of transportation and only few people use public transportation mode (Marisa *et al.*, 2020).

Campus public bus system has become an important part of university campus transportation system and many universities in their current MPs restrict private vehicular access to campus core and establish Pedestrian Priority Zones that can only be accessed by campus bus system (Clemson University CMP, 2017; Radford University CMP 2020; North Carolina State University CMP, 2023). It is in this particular that the BTS operates on campus to facilitate students and university staff mobility on campus.

c) Purpose

AAMU students have an option of using the campus BTS to facilitate their mobility on campus. The purpose of this study is to explore students perception about the operations of the campus BTS. The finding will aid students and AAMU transport department to look into the operation of the BTS to adjust its operation policies to maximize operation to better serve the student on and around campus.

i. Research questions

To understand what the perception of students on BTS is, the research will attempt to find answers to the following research questions

1. What is the main transport mode of students?
2. How do students perceive the efficiency and effectiveness of the BTS operations?
3. What service(s) do students need the BTS to change or add in its operation?
4. What is the relationship between Students BTS Efficiency Rating and Drivers Behaviors/Conducts?

Along with other statistical analysis, hypothesis testing of variable will be done to establish relationships to achieve the purpose of this research.

ii. Hypothesis Testing

1. The null hypothesis states there is no relationship between student's ratings of the BTS efficiency and drivers friendly behavior. i.e. $r = 0$ whereas the research hypothesis says that $r \neq 0$
2. There is no relationship between student ratings of the BTS efficiency and drivers knowledge of Department of Transportation (DOT) safety regulations. i.e. $r = 0$ whereas the research hypothesis says that $r \neq 0$
3. There is no relationship between students' ratings of the BTS efficiency and drivers excellent communication skills. i.e. $r = 0$ whereas the research hypothesis says that $r \neq 0$
4. There is no relation between students' ratings of the BTS efficiency and drivers excellent driving skills. i.e. $r = 0$ whereas the research hypothesis says that $r \neq 0$

II. METHODS

a) Introduction

This chapter introduces us to the methods and procedures to be followed in conducting the research. This study employed the quantitative research method in the collection and analysis of data. Descriptive statistics such as simple frequency distribution, percentages, mean, mode, variance & standard deviation, cross tabulation, graphs and charts will be used in the study. Also correlation and regression analysis will be used to establish relationships between students rating of the BTS efficiency and 4 categories of drivers behaviors.

Descriptive statistics, correlation, and regression analysis were chosen for the study because they offer valuable insights into the relationships between variables and help in understanding patterns and trends in the data. These methods were selected to analyze the data comprehensively, identify patterns, and make informed conclusions based on statistical evidence.

b) Target Population

The target population of this study involved the entire undergraduate and graduate students of the university. This target population is considered because the BTS was provided particularly to serve them and facilitate their movement on campus. The total of 6,600 students' enrolment for the fall 2023 semester was targeted to get the sample frame of the study.

c) Sampling Method

Online simple random sampling was employed in the distribution of the questionnaires. The online questionnaire link was sent to students through students' mass email and social media group platforms. This method comes with certain benefits such as being cost-effective, convenient and would ensure a greater

reliability of data since every student has equal chance of being selected to answer questionnaire. However, there are also potential drawbacks to consider, such as the risk of sampling bias and the necessity for a sufficiently large sample size in order to ensure representativeness.

d) *Data Collection Techniques*

Data collection questionnaire tool was designed using Google forms. It was designed to contain closed ended questions to enable respondents make a choice from variety of alternatives. A link to the questionnaire was shared to the researcher's supervisor and course mates for pilot test and validation before it was shared among the student populace. Students' emails and personal records such as name and phone contacts were not solicited or recorded. This technique ensured the anonymity and confidentiality of respondents.

b) *Demographic Characteristics of Respondents*

This aspect deals with the analysis of gender, age category and educational level of the respondents. The results are presented in the table below

Table 1: Gender of respondents

Gender	Frequency	Percent
Female	13	40.6
Male	19	59.4
Total	32	100.0

Table 2: Respondents age category

Age Category	Frequency	Percent
Not Responded	1	3.1
15 – 20	16	50.0
21 – 25	1	3.1
26 – 30	10	31.2
31 – 35	1	3.1
36 – 40	1	3.1
46 – Above	2	6.2
Total	32	100.0

e) *Data Analysis*

Statistical Package for Social Sciences (SPSS) and excel was used for the data analysis. These statistical tool were selected because they offer easily be used to test statistical analysis such as regression, and correlation. In order to make the analyzed data meaningful and easy to interpret, frequency tables, charts, graphs and figures will be used to present the information. Percentages will also be computed to enhance easy understanding of the collected data.

III. DATA PRESENTATION AND STATISTICAL ANALYSIS

a) *Introduction*

This aspect of the research deals with analysis of data and presentation of results.

Table 3: Respondents Level of Education

Education Level	Frequency	Percent
Doctorate	5	15.6
Freshman	15	46.9
Masters	11	34.4
Sophomore	1	3.1
Total	32	100.0

c) *Residence and Transport Mode Choice of respondents*

This part of the analysis represents the relationship between the off-campus and on-campus

residential students in relation to their mode of transport to campus. The results are presented in the bar chart below.

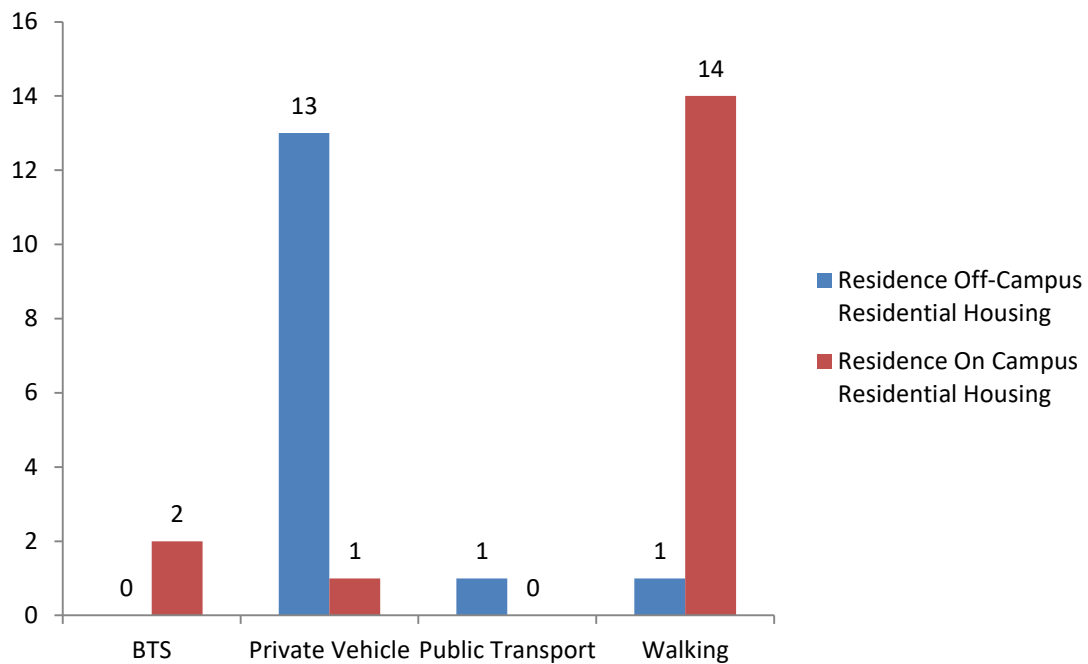


Figure 1: Residence and Transport Mode Choice of Respondents

d) *Transport Mode and Education Level Cross tabulation*

The part analyses the comparison of students' level of education against their mode of transport to campus. The results is presented in the table below

Table 4: Students Transport Mode and Level of Education

Transport Mode	Education Level				Total
	Doctorate	Freshman	Masters	Sophomore	
BTS	0	1	1	0	2
Private Vehicle	5	1	8	0	14
Public Transport	0	0	1	0	1
Walking	0	13	1	1	15
Total	5	15	11	1	32

e) *Reasons for Transport Mode*

This part of the analysis is concerned with understanding the reason why respondents use the transport mode in the above analysis.

Table 5: Reason for Transport Mode

Reasons for Transport Mode	Frequency	Percent
It is cost effective	1	3.1
It is fast and convenient	12	37.5
It is fast and convenient; It is cost effective	2	6.2
It is readily available	5	15.6
It is readily available; It is fast and convenient	4	12.5
It is readily available; It is fast and convenient; It is cost effective	2	6.2
It is readily available; It is fast and convenient; It is the only option I have. I have no other option	1	3.1
It is readily available; It is the only option I have. I have no other option	1	3.1
It is the only option I have. I have no other option	4	12.5
Total	32	100.0

f) *Respondents' Choice of Transport Mode and their Reason*

The section analysis seeks to understand why participants use the particular mode of transport to school. The result is presented in the table below.

Table 6: Reason for the Choice of Transport Mode

Reason for Transport mode choice	Transport Mode				Total
	BTS	Private Vehicle	Public Transport	Walking	
It is cost effective	0	0	1	0	1
It is fast and convenient	1	7	0	3	11
It is fast and convenient; It is cost effective	0	2	0	0	2
It is fast and convenient; It isn't really convenient but the BTS can be quite slow	0	0	0	1	1
It is readily available	0	0	0	5	5
It is readily available; It is fast and convenient	0	2	0	2	4
It is readily available; It is fast and convenient; It is cost effective	0	1	0	1	2

It is readily available; It is fast and convenient; It is the only option I have. I have no other option	0	1	0	0	1
It is readily available; It is the only option I have. I have no other option	0	0	0	1	1
It is the only option I have. I have no other option	1	1	0	2	4
Total	2	14	1	15	32

g) BTS Effectiveness

This section attempts to gauge students thinking about the BTS serving its purpose effectively. The question was asked as follows "The BTS goal is to ensure students' safety and to make students' lives on

campus easier by busing them around the university's beautiful campus. *Do you think the BTS is serving its purpose effectively?*" The results of the responses are presented below in a line graph

BTS Effectiveness

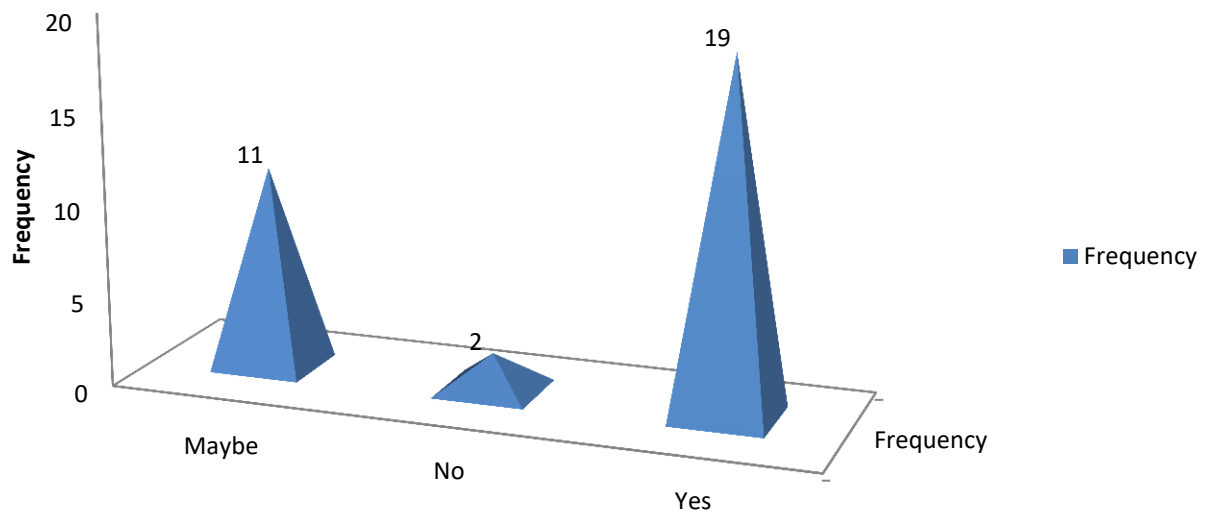


Figure 2: Students perception about the BTS serving its purpose effectively

h) Rating of the Efficiency of the BTS

Students were asked to rate the efficiency of the BTS operations on a scale of 1 to 5 where; 1 means strongly efficient, 2 means fairly efficient, 3 means I am neutral, 4 means fairly inefficient, and 5 means strongly inefficient. The result is presented below.

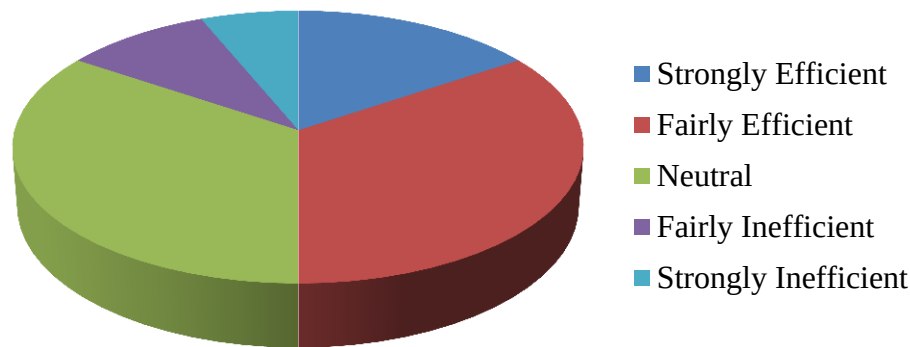


Figure 3: Students Rating of the Efficiency of the BTS Operations

i) *BTS Improvement Recommendation*

Students were asked to recommend areas that they think need to improve in the BTS operations. A set

of possible recommendations were given for them to select and the results is presented in the table below.

Table 7: Respondents' Recommendation for improvement in the BTS operations

Recommendation	Frequency	Percent
Develop app for students to track bus daily schedule	10	31.2
Establish more Stations, and create new routes	6	18.8
Provide regular off-campus services	8	25.0
Reduce the waiting time at the station	4	12.5
Renovate Bus Stations with Shelter	4	12.5
Total	32	100.0

j) *Students' Recommendation for BTS Improvement Based on their Residence*

The analysis further explored to understand how students will recommend for the BTS operation

improvement based on their place of residence – i.e. those residents on campus and off-campus housing using cross tabulation. The result is presented in the table below.

Table 8: Students Recommendation for BTS Improvement based on their residence

Recommendation	Frequency	Percent
Develop app for students to track bus daily schedule	10	31.2
Establish more Stations, and create new routes	6	18.8
Provide regular off-campus services	8	25.0
Reduce the waiting time at the station	4	12.5
Renovate Bus Stations with Shelter	4	12.5
Total	32	100.0

k) *Students Rating of BTS Drivers' Behavior/Conduct*

On a scale of strongly agree, Agree, Neutral, Disagree, and strongly Disagree, students were asked to rate the BTS drivers behavior/conduct on variables including Drivers are Friendly, Know DOT safety regulations, Have excellent communication, and Have excellent driving skills.

Table 9: Students Rating of BTS drivers' behavior/conduct

Driver behavior	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Total
Drivers are Friendly	18 (56.2%)	7 (21.9%)	6 (18.8%)	1 (3.10%)	0 (0.0%)	32 (100%)
Drivers know DOT safety regulations	17 (53.1%)	8 (25.0%)	7 (21.9%)	0 (0.00%)	0 (0.00%)	32 (100%)
Drivers have excellent communication skills	14 (43.8%)	8 (25.0%)	10 (31.2%)	0 (0.00%)	0 (0.00%)	32 (100%)
Drivers have excellent driving skills	19 (59.4%)	9 (28.1%)	4 (12.5%)	0 (0.00%)	0 (0.00%)	32 (100%)
Total	68 (53.1%)	32 (25.0%)	27 (21.1%)	1 (0.8%)	0 (0.00%)	128 (100%)

j) *Regression Analysis of Students BTS Efficiency Rating Based on Drivers Behavior*

This section uses regression analysis and Analysis of Variance (ANOVA) to test hypothesis and

determine the relationship between Students BTS Rating (X) based on their perception of the Drivers behavior (Y). Using excel to run the statistical analysis, the results is presented in the table below.

Table 10: Regression Statistics of Students BTS ratings (X) and Drivers are friendly (Y)

Regression Statistics	
Regression coefficient (r)	0.589999
Coefficient of Determination (r ²)	0.348099
Coefficient of non-determination	0.651901
Standard Error	0.735210
Intercept(a)	0.428571
Slope (b)	0.491289
Observations (N)	32
Regression equation model	$\hat{Y} = 3.71 + 0.41x$

i. *Hypothesis Testing of Drivers Friendly behavior (Y)*

The null hypothesis states there is no relationship between student ratings of the BTS

efficiency and drivers friendly behavior i.e. $r = 0$ whereas the research hypothesis says that $r \neq 0$

Table 11: ANOVA Summary Table for drivers' friendly behavior data

	df	SS	MS	F	Significance F
Regression	1	8.66	8.66	16.02	0.00037932
Residual Error	30	16.22	0.54		
Total	31	24.87			

Table 12: Regression Statistics of Students BTS ratings (X) and Drivers knowledge of DOTsafety regulations (Y)

Regression Statistics	
Multiple Regression Coefficient (r)	0.461341146
Coefficient of Determination (r^2)	0.212835653
Coefficient of Non-determination	0.787161347
Standard Error	0.7400913
Intercept (a)	0.785714286
Slope (b)	0.351916376
Observations	32
Regression Equation Model	$\hat{Y} = 0.79 + 0.35X$

- ii. *Hypothesis Testing of Drivers DOT Safety Knowledge Behavior (Y)* knowledge of DOT safety regulations i.e. $r = 0$ whereas the research hypothesis says that $r \neq 0$.

Null Hypothesis: There is no relationship between student ratings of the BTS efficiency and drivers

Table 13: ANOVA Summary Table for drivers' road safety knowledge data

Regression Statistics	
Regression Coefficient (r)	0.087552871
Coefficient of Determination (r^2)	0.007665505
Coefficient of non-determination	0.992334495
Standard Error	0.953750467
Intercept (a)	1.428571429
Slope (b)	0.076655052
Regression Equation Model	$\hat{Y} = 1.43 + 0.08X$
Observations	32

Table 14: Regression Statistics of Students BTS ratings (X) and Drivers' communication skills(Y)

Regression Statistics	
Regression Coefficient (r)	0.087552871
Coefficient of Determination (r^2)	0.007665505
Coefficient of non-determination	0.992334495
Standard Error	0.953750467
Intercept (a)	1.428571429
Slope (b)	0.076655052
Regression Equation Model	$\hat{Y} = 1.43 + 0.08X$
Observations	32

iii. *Hypothesis Testing of Drivers Excellent Communication Skills*

There is no relationship between students' ratings of the BTS efficiency and drivers excellent

communication skills i.e. $r = 0$ whereas the research hypothesis says that $r \neq 0$

Table 15: ANOVA Summary table for Drivers Excellent Communication Skills

	df	SS	MS	F	Significance F
Regression	1	0.210801394	0.210801394	0.231741573	0.633728395
Residual	30	27.28919861	0.909639954		
Total	31	27.5			

Table 16: Regression Statistics of Students BTS ratings (X) and Drivers' excellent driving skills

Regression Statistics	
Regression coefficient (r)	0.436078899
Coefficient of Determination (r^2)	0.190164806
Coefficient of non-determination	0.809835194
Standard Error	0.65655809
Intercept (a)	0.785714286
Slope (a)	0.290940767
Regression Equation Model	$Y = 0.79 + 0.29X$
Observations	32

iv. *Hypothesis Testing of Drivers Excellent Driving Skills*

There is no relation between students' ratings of the BTS efficiency and drivers excellent drivingskills i.e. $r = 0$ whereas the research hypothesis says that $r \neq 0$

Table 17: ANOVA Summary table for Drivers Excellent driving Skills

	df	SS	MS	F	Significance F
Regression	1	3.036694251	3.036694251	7.044574296	0.012595765
Residual	30	12.93205575	0.431068525		
Total	31	15.96875			

IV. DISCUSSIONS

a) Introduction

This part of the research discusses the findings of the analysis and results in the data presentation and statistical analysis sections.

b) Discussion of Demographics

The data presented in Table 1 reveals that out of the total respondents, 59.4% were males, whereas 40.6% were females. Moving on to Table 2, which highlights the age distribution of the respondents, it was found that 50% of the respondents fell under the age group of 15-20, which was the modal class. This suggests that most respondents were young adults who had just entered the early stages of adulthood. The age group of 26-30 had 10 respondents, representing 31.2% of the total, indicating that a significant portion of the

respondents belonged to the age group that is typically considered to be in the prime of their lives. On the other hand, the age group of 46 and above had only 2 respondents, representing 6.2% of the total. This suggests that there were very few respondents who were older adults. The remaining age groups of 21-25, 31-35, and 36-40 had 1 respondent each, representing 3.1% of the total. It is worth mentioning that one respondent did not provide their age, which could impact the overall findings.

Moreover, Table 3 provides insights into the respondents' education level. It was found that 46.9% of the respondents were first-year students, indicating that most were in their first year of college or university. This suggests that the sample was comprised primarily of first-time college students. In addition, 34.4% were master's students, indicating that a significant portion of

the respondents were pursuing graduate-level studies. Furthermore, 15.6% were pursuing a doctorate, meaning that a few respondents were in the final stages of their academic careers. Interestingly, only 3.1% were sophomores, which suggest that very few respondents were in their second year of college or university. No respondents were at a junior or senior level, which indicates that first-year and graduate-level students dominated the sample.

c) *Discussion of the Residence and Transport Mode Choice of Respondents*

In examining the Figure 1 bar chart, it is evident that a significant proportion of students who reside in on-campus residential apartments (44%) prefer to walk to campus, while only a small percentage (6%) use the BTS. Only one respondent uses a private vehicle. In contrast, most off-campus residential students (41.1%) generally use private cars to commute to campus, with only one using public transport and another student walking to campus.

From these findings, it can be concluded that on-campus students prefer walking over utilizing the bus system to commute to campus. In contrast, off-campus students favor private means of transport over public transport.

The implications of the on-campus preference for walking could mean increased active mobility on campus, which could help prevent the creation of heat islands as fewer vehicles are used. This aligns with the active mobility objectives outlined in the 2014 campus master plan of the university and the net zero policy of the Huntsville city plan. However, this approach also presents serious concerns related to pedestrian safety, as it combines pedestrian mobility with vehicular traffic on campus. Overall, these findings could inform transportation policies and decisions on infrastructure development, such as bike lanes, pedestrian walkways, or bike-share services to promote sustainable and active mobility on campus while reducing carbon emissions and promoting a healthier lifestyle for students.

d) *Discussion of the Transport Mode and Education Level Cross tabulation*

Based on the data presented in Table 4, it is evident that the preferred mode of transportation to campus varies among different academic levels. Most freshmen students, comprising 13 out of 15 respondents, equivalent to 87%, prefer walking to campus. In contrast, only one student each, which accounts for 7%, uses the BTS or private vehicles. Interestingly, none of the doctorate students use any other mode of transportation except for private vehicles, while almost 73% of the master's students, comprising eight out of eleven respondents, prefer using private vehicles. Out of all the master's students, only one student each, which is equivalent to 9%, opt for the BTS, public transportation, and walking, respectively. As for

sophomores, the only respondent included in the data prefers to walk to campus.

In conclusion, the data suggests that first-year students usually walk to campus. In contrast, students at higher academic levels, such as master's and doctorate students, tend to prefer using private vehicles. The data also indicates that the BTS and public transportation are not popular choices among the respondents.

e) *Discussion of the Reasons for Respondents' Transport Mode*

According to the findings presented in Table 5, a majority of 12 students, which accounts for 37.5% of the total respondents, stated that they use their current mode of transport because it is fast and convenient. Additionally, 5 students (15.6%) mentioned that the reason for their current mode of transport is that it is readily available. 4 students (12.5%) reported that they use their current transport mode because it is readily available, fast, and convenient, whereas another 4 students (12.5%) stated that they use it because they have no other option.

Furthermore, 2 students (6.2%) selected each of the following categories: "it is fast and convenient; it is cost-effective" and "It is readily available; it is fast and convenient; it is cost-effective". These findings provide valuable insights into the factors that influence students' transportation decisions.

f) *Discussion of Respondents' choice of Transport Mode and their Reason*

According to the findings presented in Table 6, it can be deduced that out of all the respondents, only two of them use the BTS as their mode of transportation to campus. One of the respondents indicated that using BTS was their only option and that it is fast and convenient. On the other hand, among the 14 students who use a private mode of transport, seven of them (47%) believe that it is fast and convenient, while two of them (13%) mentioned that it is cost-effective. An additional two students (13%) stated that private transport is readily available. The only student who uses public transportation thinks that it is cost-effective.

Furthermore, when it comes to students who prefer walking to the campus, the majority of five students (33%) considered walking as a readily available mode of transportation, while three students (20%) found it fast and convenient. Interestingly, one student who walks to the campus indicated that it is faster than the BTS.

To sum up, the research findings suggest that students prioritize fast movement and convenience when selecting their mode of transportation to campus. It also shows that there is a perception among students that the BTS is relatively slow. Perceptions of BTS speed are crucial as they impact the overall satisfaction and usage of public transportation services on campus.

Addressing concerns about speed can lead to improvements in service frequency, route optimization, and overall efficiency, enhancing the attractiveness of public transportation as a viable option for campus commuters.

g) *Discussion of Student Perception of BTS Effectiveness*

According to the results depicted in Figure 2, most students surveyed have a positive perception of the BTS. Out of the total number of respondents, which was 32, 19 students (59.38%) answered "yes" when asked if they believe the BTS is serving its purpose effectively. On the other hand, 11 students (34.38%) answered "maybe," while only 2 students (6.25%) answered "no." These results suggest that the general consensus among students is that the BTS is functioning well and serving its intended purpose.

However, it is important to note that the number of students who participated in the survey may not necessarily represent the views of the entire student population. Additionally, even though the BTS is perceived to be effective, the low number of students who use it suggests a need for further promotion or improvements to increase its usage.

h) *Discussion of Students' Rating of the Efficiency of the BTS*

From the figure 3, 11(34.4%) think the BTS operations is fairly efficient, while another 11(34.4%) indicated they are indifferent. 5(15.6%) think its operation is strongly efficient. Only 5 disagree and indicated it is fairly inefficient (9.4%) and strongly inefficient (6.2%). Therefore, this finding suggests that students think generally the BTS operation is efficient.

i) *Discussion of BTS Improvement Recommendation*

According to the findings presented in Table 7, the majority of the surveyed students, comprising 31.2% or 10 students expressed their desire for the BTS management to develop an app that would enable them to track the daily schedule and movement of the buses. 25% or 8 students, on the other hand, opined that BTS should provide regular off-campus services. 18.8% or 6 students suggested that the management should establish more stations and create new routes. Meanwhile, 12.5% or 4 students each wanted the management to reduce the waiting time at the stations and renovate the bus stations with proper shelter.

Based on these results, there is a strong demand among the students for the development of an app to track the movement schedules of the buses, as well as for the provision of regular off-campus services. Such an app can provide real-time information on transportation schedules, routes, and vehicle locations, improving the overall convenience and efficiency of campus transportation services. Integrating technology-driven solutions like tracking apps can enhance user

satisfaction and promote the use of sustainable transportation modes.

j) *Students' Recommendation for BTS Improvement Based on their Residence*

The data obtained from Table 8 shows that 46.7%, which is equivalent to 7 out of the 15 students who stay off-campus, are in favor of the BTS providing regular off-campus services. This suggests that a significant proportion of off-campus students rely on private transportation as there are currently no reliable regular off-campus services available. Furthermore, 26.7% of the off-campus students (4 in number) recommend developing an app that can help them track the daily movement schedule of buses.

Meanwhile, 20% (3 students) suggest that the bus stations should be renovated to provide shelter, and only 6.7% (1 student) recommend reducing the waiting time at the stations.

On the other hand, the majority of on-campus residential students, which is 35.3% (6 in number), recommended developing an app that can help track the daily movement schedule of buses. They also suggested establishing more service stations and creating new routes. Additionally, 17.6% (3 students) of the on-campus residential students recommended reducing the waiting time at the stations. In comparison, only 5.9% (1 student) recommended providing off-campus services and renovating bus stations with shelter.

From this analysis, we can infer that students who stay on campus want more service stations and routes and an app to track bus movement. This is because they might not be able to track the whereabouts of buses, and would rather walk than miss their schedules if the buses do not appear on time (refer to figure 1). The desire for a tracking app highlights the importance of technology in enhancing the overall transportation experience. On the other hand, students who stay off-campus recommend regular off-campus services because they might be relying on private means of transportation (refer to figure 1), because there are currently no reliable off-campus regular services available.

k) *Discussion of Students' Rating of BTS Drivers' Behavior/Conduct*

According to the results presented in Table 9, the perception of the students regarding various variables related to the drivers' performance has been analyzed. The data shows that a majority of the students strongly agree that the drivers are friendly, with 56.2% of the respondents confirming this statement. Additionally, 21.9% of the students agree with this statement, while only 18.8% remained neutral. Only a small percentage of students, 3.10%, disagreed with the statement, and none of them strongly disagreed with it.

When it comes to the drivers' knowledge about DOT safety regulations, 53.1% of the respondents strongly agree that the drivers possess this knowledge. Similarly, 25% agreed with this statement, while 21.9% stayed neutral towards it. Interestingly, no student disagreed or strongly disagreed with this statement.

Similarly, for the variable of "drivers have excellent communication skills," a majority of the students agreed with the statement, with 43.8% strongly agreeing and 25% agreeing. On the other hand, 31% of the respondents selected a neutral response. However, no student disagreed or strongly disagreed with this statement.

Regarding the drivers' driving skills, 59.4% of the respondents strongly agreed that the drivers have excellent driving skills. 28.1% agreed with the statement, while 12.5% opted for a neutral response. In general, the responses showed that 53.1% of the respondents strongly agreed with the statements, 25% agreed, and 21.1% remained neutral. Only a negligible percentage of 0.8% of the responses disagreed with the statements.

Overall, the analysis of the data suggests that the students generally agree that the drivers are friendly, knowledgeable about safety regulations; possess excellent communication skills, and driving skills.

These positive perceptions can contribute to overall student satisfaction with the university's transportation services. When students have positive experiences with drivers and efficient transportation services, it can enhance their overall satisfaction with the university's transportation system. The potential implications for the university's transportation management include the need to prioritize driver training and behavior management to maintain positive perceptions among the students.

l) Discussion of Regression Statistics of Students BTS ratings and Drivers are friendly

According to the information in table 10, the correlation coefficient (r value) between drivers being friendly and students' rating of BTS efficiency is 0.60, indicating a strong positive correlation between these two factors. Furthermore, the coefficient of determination (r^2) reveals that 35% of the variance in drivers' friendly behavior can be attributed to students' evaluations of BTS operation efficiency. However, the remaining 65% of the residual variance cannot be explained by this factor alone. This suggests that other factors might be influencing the drivers' behaviors, such as their communication skills, driving abilities, or knowledge of the Department of Transportation (DOT) safety regulations. Overall, this information suggests that while students' evaluations of BTS efficiency can explain a significant portion of drivers' friendly behavior, there are likely other factors at play as well.

m) Discussion of Hypothesis Testing Results of Drivers Friendly Behavior (Y)

Based on the analysis of Table 11, it has been observed that the calculated F value of 16.02 is considerably higher than the critical value. This indicates that the independent variable, which is students' ratings of BTS efficiency, is a significant contributor to the variance in students' perception of the BTS drivers being friendly. As a result, there is a strong correlation between the two variables.

Therefore, it can be concluded that the research hypothesis, which suggests a relationship between students' perception of the drivers being friendly and their rating of BTS operation efficiency, is valid and can be accepted. This finding highlights the importance of effective BTS operation management in creating a positive image of drivers among students and improving their efficiency.

n) Discussion of Regression Statistics Results of Students BTS Ratings (X) and Drivers Knowledge of DOT Safety Regulations (Y)

The statistical analysis of the data presented in Table 12 reveals a moderate positive correlation between drivers' knowledge of DOT safety regulations and students' rating of the BTS efficiency, with an r -value of 0.46. This suggests that as students' ratings of the BTS operation efficiency increase, so does their perception of drivers' knowledge of safety regulations. The coefficient of determination (r^2) indicates that approximately 21% of the variation in drivers' safety knowledge can be explained by the ratings of the BTS operation efficiency provided by the students. However, the coefficient of non-determination of 79% implies that a significant amount of variance in drivers' road safety knowledge remains unexplained by students' ratings of the BTS operation efficiency. This could be the reason why the correlation, while positive, is not particularly strong.

Furthermore, the intercept (a) of the regression equation suggests that if a student did not rate the BTS efficiency (i.e., X equals zero), they would still give the driver's knowledge of safety regulations ($\hat{Y}$) a rating of 0.79. The slope (b) of the regression equation indicates that for each additional rating of the BTS efficiency a student provides, they tend to give 0.35 more rating of the drivers' knowledge of safety regulations.

Overall, these findings suggest that while students' ratings of the BTS operation efficiency may be a useful indicator of drivers' knowledge of safety regulations, there are other factors that contribute to drivers' safety knowledge that are not captured by this measure.

o) Discussion of Hypothesis Testing Results of Drivers DOT Safety Knowledge Behavior

The analysis results in Table 13 reveal that the calculated F value, which is 8.11, is significantly higher

than the critical value of F at both the 0.05 and 0.01 significance levels, that is, 4.17. This indicates that the independent variable, which in this case is the students' rating of BTS efficiency, explains a significant amount of the variance in the students' perception of the BTS drivers' knowledge of road safety regulations.

Therefore, we can conclude that the research hypothesis that there is a relationship between the two variables is valid. Specifically, it can be said that the students' perception of the drivers' knowledge of road safety rules plays a significant role in how they rate the overall efficiency of the BTS operation.

p) Discussion of Regression Statistics of Students BTS ratings (X) and Drivers' Communication Skills (Y)

According to the data presented in Table 14, there is a positive weak correlation (0.09) between the efficiency ratings of students regarding the BTS operation (X) and the communication skills of drivers (Y). The r^2 value of 0.76% suggests that only a small portion of the variance in drivers' excellent communication skills can be explained by the students' ratings of the BTS operation efficiency.

On the other hand, the coefficient of non-determination of 99.23% indicates that a significant portion of the variance in drivers' excellent communication skills remains unexplained by the students' ratings of the BTS operation efficiency. Additionally, the large standard error of 95.37% suggests that the results may not be representative of the entire population.

q) Discussion of Hypothesis Testing results of Drivers Excellent Communication Skills

Based on the analysis of the data provided in Table 15, it has been observed that the calculated F value is 0.23, which is less than the critical value of F at the .05 and .01 significance levels, i.e., 4.17. This implies that the significance F (0.63) is greater than the calculated F value, indicating that the independent variable (students' ratings of BTS efficiency) explains an insignificant variance in students' perception of the BTS drivers' knowledge of road safety regulations. Therefore, there is no significant relationship between these two variables. This further affirms the weak correlation between the two variables.

Based on the above observation, we can conclude that we accept the null hypothesis, which states that there is no relationship between students' perception of the efficiency of the BTS operation and the drivers' communication skills. In other words, the data does not provide evidence to support the assumption that there is a significant relationship between these two variables.

r) Discussion of Regression Statistics of Students BTS ratings (X) and Drivers' Excellent Driving Skills

The statistical analysis conducted on the data in Table 16 revealed that the correlation between students'

ratings of BTS efficiency and drivers' driving skills is moderately positive, with an r value of 0.44. This means that as the students' ratings of BTS efficiency go up, so do their ratings of the drivers' driving skills.

Additionally, the r -squared value of 0.19 (19%) indicates that 19% of the variance in drivers' driving skills can be explained by the students' ratings of BTS efficiency. In other words, taking into account the students' ratings of BTS efficiency can reduce the error in predicting their perception of the drivers' driving skills by 19%.

However, it is important to note that the coefficient of non-determination of 0.81 (81%) indicates that the remaining 81% of the variance in drivers' excellent driving skills is not explained or accounted for by the students' ratings of BTS operation efficiency.

Lastly, the standard error of 66% represents the discrepancy or deviation in establishing the relationship between the students' BTS ratings and drivers' driving skills. This suggests that there may be other factors that influence students' ratings of drivers' driving skills, and that this relationship should be interpreted with caution.

s) Discussion of Hypothesis Testing Results of Drivers Excellent Driving Skills

Based on the data presented in Table 17, a calculated F value of 7.04 was obtained. Comparing this value with the critical value of F at the .05 and .01 significance levels (4.17), it was found that the calculated F value was greater than the critical value. This means that the result is statistically significant and falls outside the null hypothesis acceptance zone. Consequently, the researcher's hypothesis that there is a relationship between students' ratings of the BTS efficiency and drivers' driving skills is accepted. It should be noted that the relationship is moderate in nature. In summary, the obtained findings suggest that there is indeed a significant relationship between students' ratings of the BTS efficiency and drivers' driving skills, even though this relationship is not very strong.

t) Summary of Research Discussion Findings

1. Students who stay on campus majority of whom are freshmen prefer to walk than to use the bus system to campus. However, off-campus students usually made of masters and doctorate students prefer using private means to campus to the public transport. Reasons were that both public transport and the BTS are not fast and reliable.
2. Students prioritize fast movement and convenience in selecting their transport mode to campus giving a perception that the BTS is quiet slow even though they perceived the BTS to be serving its purpose effectively and operates efficiently.
3. Students want management to develop app to track the buses movement schedules and provide off-campus regular services because majority of off-

campus students use their private means because there is no reliable off campus regular services.

4. Students generally agree that drivers are friendly, know safety regulations, and have excellent communication and driving skills.
5. There is a strong positive relationship between students' perception that the drivers are friendly and their rating of the BTS operation efficiency.
6. Students' perception that the drivers' knowledge of road safety rules has an influence on how they rate the BTS operation efficiency – there is a moderate positive relationship.
7. However, the analysis found no relationship between students perception of the efficiency of the BTS operation and drivers communication skills.
8. There is a moderate positive relationship between students' ratings of the BTS efficiency and drivers driving skills.
9. Even though there are somewhat relationships the standard predictor errors were high suggesting that the data used in the analysis may not be a sufficient representation of accurate predictions for the entire student population.

u) Conclusion

Students generally have a positive perception of the BTS operations even though many of them do not use it to move around campus. Also, students agree that drivers are friendly, know road safety regulations, and have excellent communication and driving skills. The research results also established a positive

correlation between the efficiency and effectiveness of the bus system and how students perceive it.

However, it is worth that there were varying degrees of strength in these relationships, with high standard errors among the dependent variables. In other words, while the survey findings suggest that students generally view the BTS system favorably, their perception of its efficiency and effectiveness is influenced by several factors. Incorporating these findings into planning and policy-making processes can lead to more effective and user-centric transportation solutions for the campus.

V. RECOMMENDATIONS FOR FURTHER RESEARCH

1. An extension of the research could be done to explore the reasons behind the positive perception despite low BTS usage.
2. Research can be done to explore other factors that could have influenced the respondents' choice of transportation mode, such as distance from campus or availability of parking spaces.
3. Further research can be done to evaluate the safety of pedestrians and cyclists on campus.
4. Lastly, with the increasing awareness of the need for sustainable development, finding ways to reduce carbon emissions and promote eco-friendly transportation modes is essential. Therefore, research can be done to assess the environmental impacts of transportation to help mitigate its effects.

VI. LIST OF ABBREVIATIONS

AAMU.....	Alabama Agricultural and Mechanical University
CMP.....	Campus Master Plan
FTA.....	Federal Transit Authority
BTS....	Bulldog Transit System
DOT.....	Department of Transportation
SPSS.....	Statistical Package for Social Sciences
ANOVA.....	Analysis of Variance

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GLOBAL JOURNAL OF HUMAN-SOCIAL SCIENCE: B
GEOGRAPHY, GEO-SCIENCES, ENVIRONMENTAL SCIENCE & DISASTER
MANAGEMENT

Volume 24 Issue 1 Version 1.0 Year 2024

Type: Double Blind Peer Reviewed International Research Journal

Publisher: Global Journals

Online ISSN: 2249-460X & Print ISSN: 0975-587X

Overview of Brazilian Malaria Incidence from Environmental, Economic and Spatial Factors in Amazon and Extra Amazon Region

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Abstract- Malaria is caused by the protozoan Plasmodium and its infection can occur in several ways, being the most common through the bite of the female mosquito Anopheles darlingi. The life cycle of the vector is related to the dynamics of the ecosystem that lives, situations such as global warming generate a great concern regarding the possible amplification of the reproduction capacity of vectors according to climate change. These diseases are much more frequent in regions where the climate is tropical, such as Brazil. The incidence of the vector is characterized by several factors, such as biological, ecological, sociopolitical, cultural, and economic factors, the latter influence health expenditures in Brazil regarding the preventive measures of infection. The economic impact includes expenses with any health care, lost service days, loss of classes in the education system, as well as lower-income at work due to brain injuries, among others. Malaria breeds poverty and poverty breeds Malaria.

Keywords: anopheles darlingi, plasmodium, brazil, vector-borne diseases.

GJHSS-B Classification: (LCC): RC845



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Overview of Brazilian Malaria Incidence from Environmental, Economic and Spatial Factors in Amazon and Extra Amazon Region

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Abstract- Malaria is caused by the protozoan *Plasmodium* and its infection can occur in several ways, being the most common through the bite of the female mosquito *Anopheles darlingi*. The life cycle of the vector is related to the dynamics of the ecosystem that lives, situations such as global warming generate a great concern regarding the possible amplification of the reproduction capacity of vectors according to climate change. These diseases are much more frequent in regions where the climate is tropical, such as Brazil. The incidence of the vector is characterized by several factors, such as biological, ecological, sociopolitical, cultural, and economic factors, the latter influence health expenditures in Brazil regarding the preventive measures of infection. The economic impact includes expenses with any health care, lost service days, loss of classes in the education system, as well as lower-income at work due to brain injuries, among others. Malaria breeds poverty and poverty breeds Malaria. Through the Factorial Planning method: A brief review, data were collected in all Brazilian regions affected by the disease. The research strategy consisted of the use of the keywords in English: 1. Climate Change in Brazil; 2. *Anopheles Darling* vector life cycle; 3. Impact of climate change on the life cycle of *Anopheles Darling*; 4. Sensitive socioeconomic factors. Finally, this set of data suggests that public health programs act strategically in the population conjuncture, on the fronts of prevention, diagnosis, and treatment of the disease.

Palavras Chave: *anopheles darlingi*; *plasmodium*; brazil; vector-borne diseases.

1. INTRODUCTION

The oldest known diseases in the world are those transmitted through vector mosquitoes. Reports of the papyri of Éber (3550 BC) mention that during the floods of the Nile River many people were affected

by an intermittent fever, body pain, and yellowing of mucous membranes, many cities were decimated by the disease (SHEIBAN, 2006). There were beliefs that the disease was derived from the stench of the swamps, contaminated air and for a long time there was no scientific progress about the etiology of the disease (FAUSTINO, 2016).

Currently, it is known that the protozoan *Plasmodium* (Apicomplexa) causes Malaria disease and its infection can occur in several ways, being the most common through female mosquito bite by *Anopheles darlingi* (GITTA, 2020). After the bite, assuming that the mosquito is contaminated with the protozoan, it is inoculated in the forms of sporozoites, which migrate to the human liver where they reproduce asexually (ORFANÓ, 2016).

The vector life cycle is directly related to the ecosystem dynamics in which they live, situations such as global warming, generate a great concern regarding the possible amplification of the reproduction capacity of vectors according to climate change. However, the climate relationship and the incidence of malaria transmission are still little studied, besides having a very complex relationship that varies according to the studied site. This kind of disease is much more frequent in regions where the climate is tropical, such as Brazil (FERREIRA 2015).

According to data collected by the Foundation of Health Surveillance, many regions situated in North Brazil, such as Amazonas State can be classified as "high risk" according to the malaria case record data.

The lack of information in hard-to-reach regions on malaria prevention and treatment methods makes it difficult to control the disease, leading people to believe that Malaria can be transmitted through the ingestion of water and food. Citing analogous cases, in villages, it is believed that herbal tea can minimize the symptoms of the disease and even cure the infected (WOLFHART-COUTO, 2020). Issues involving climate change and its impact on human health should be analyzed and discussed to propagate current information and future perspectives on new alternatives for prevention, diagnosis, and more effective treatments (OMS, 2015).

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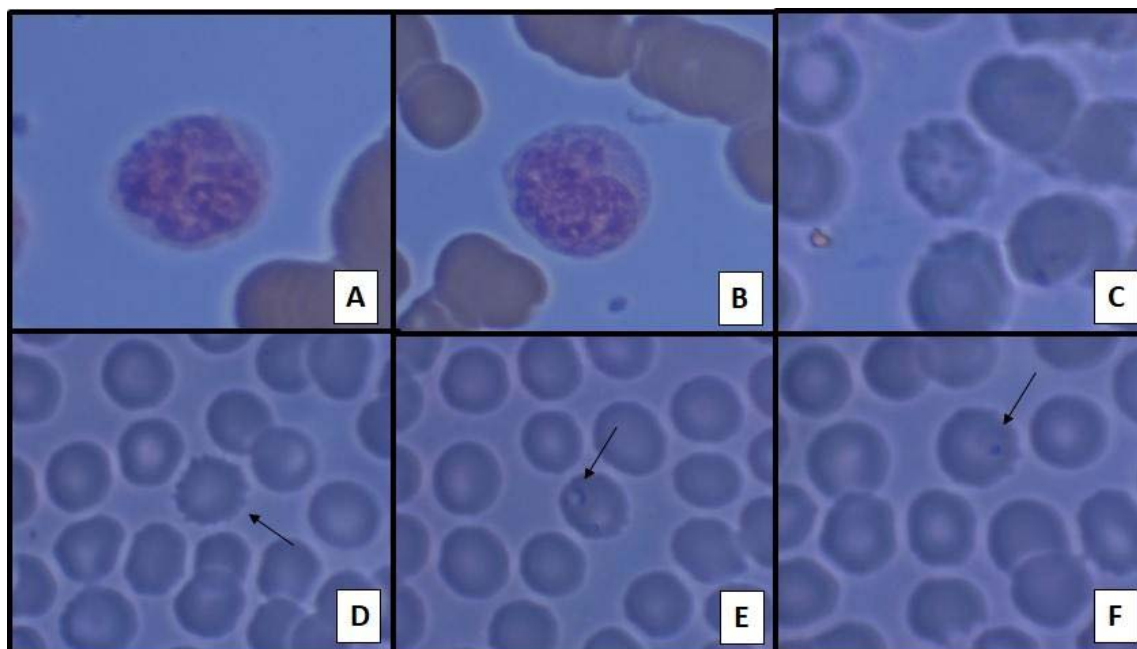
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a) *Species and morphology of the parasite Plasmodium spp.*

Malaria's laboratory diagnostic manual (2009) says that parasites of the genus *Plasmodium*, vary in size, shape, and appearance, confusing with foreign elements such as fungi, bacteria, and other protozoa and thus hindering the diagnosis of Malaria. Microscopically the shapes of the species resemble rings, schizonts, and gametocytes are rounded.

For the distinction among *Plasmodium* species, blood smears are the best method because allow analyzing the shape and diameter of infected human red blood cells (Fig. 1) (FERREIRA, 2012).

Plasmodium falciparum has an erythrocytic form with trophozoites and small formation, hyaline and annulate inside the parasitized red blood cells and ameboid movement not as intense as in *Plasmodium vivax*. After Giemsa staining, the parasite reveals blue staining in the cytoplasm and cracks in the stroma of the red blood cells, called Maurer granulations, and is observed in the initial phase of the parasite in the red blood cell. Gametocytes are elongated and curved with slightly tapered extremities (Fig 1) (REY, 2008).



Source: Prepared by the author (2020).

Figure 1: A and B: *Plasmodium vivax* Schizont forms; Multiparasitic red blood cells by trophozoites of *Plasmodium falciparum*; D: Red blood cells infected by *Plasmodium* sp. associated with the formation of knobs (arrow); E and F: Trophozoite of *P. falciparum* into red blood cells with ring form (arrow).

Plasmodium vivax has an erythrocytic and young trophozoites as a rounded disc of intense activity inside the red blood cell, the refringent nucleus appears as a bright granule. In the corded preparations (Giemsa) the young trophozoite appears in the form of a small blue mass of cytoplasm, ovoid or rounded with dense chromatin and strongly colored red. As the cell membranes of erythrocytes change, they emit a thin red granulation flame of Schüffner. In pre-schizonts, the cytoplasm is more abundant, and the pigment granules are larger and darker. Gametocytes appear later than the trophozoites. Female gametocytes present almost the entire volume of dilated red blood cells (10-11 µm in diameter). They are usually 3 to 8 times more frequently than males. Microgametocytes are slightly smaller and have pale blue cytoplasm (REY, 2008).

Plasmodium malariae has less active trophozoites than *P. vivax* and performs the sluggish

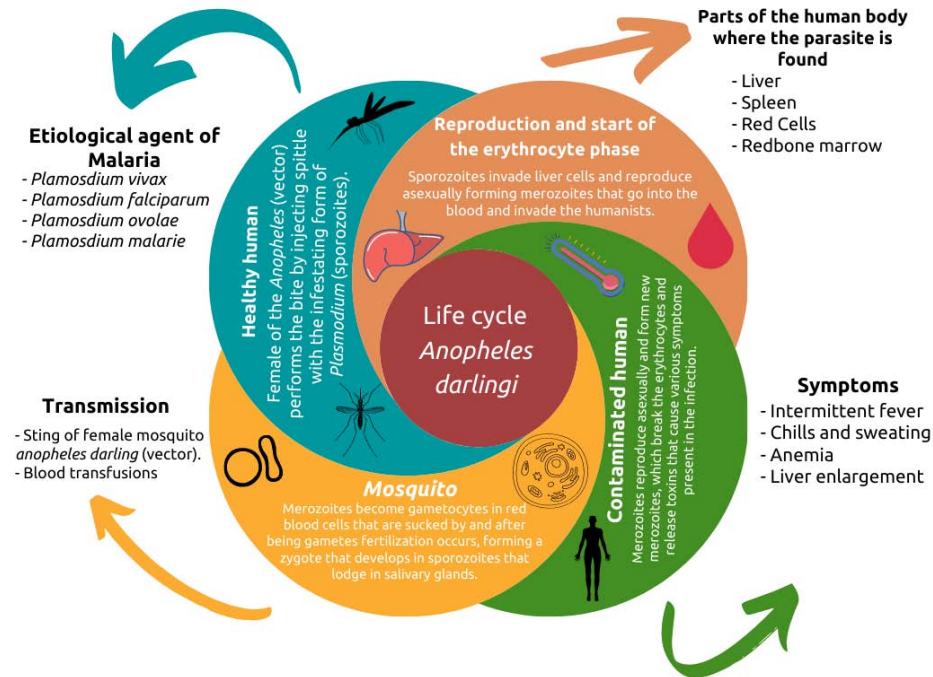
movement. In the cytoplasm, pigment grains are few numerous, however, it has the largest volume than the other *Plasmodium*. Young trophozoites are the first to appear in the bloodstream, exhibit in ring form, occupying one-third of the diameter of red blood cells. In *P. malariae* infections there are no Schüffner granulations and there are rare occasions that changes occur called Ziemann granulations that are larger and coarser than Schüffner. The merozoite forms from 6 to 12 merozoites arranged as the petal of a flower in the residual cytoplasm, where the entire pigment is stored. Gametocytes have almost the same morphology as *P. vivax*, differing only that their size is smaller (REY, 2008).

b) *The life cycle of Plasmodium sp.*

malaria cycle begins when the female *Anopheles* sp. injects, through saliva, *Plasmodium* sporozoites, into the human bloodstream. The pre-

erythrocytic phase occurs in the liver, where sporozoites migrate and develop into schizonts. These schizonts rupture by releasing merozoites and infecting erythrocytes and then the parasite multiplies asexually (the so-called erythrocyte cycle). Merozoites develop

into ring-stage trophozoites and some of these mature for schizont that breaks up releasing merozoites. Next, some trophozoites differ in gametocytes (ASHLEY, PHYO, WOODROW 2018).



Source: Prepared by the author (2020), adapted on Merck & Co (2020).

Figure 2: *Plasmodium* life cycle.

During blood intake, the mosquito ingests male (microgametocytes) and female (macrogametocytes) gametocytes, starting the sporogonic cycle. In the mosquito stomach, microgametes penetrate macrogametes, producing zygotes. These zygotes become mobile and elongated, evolving to oocinets that invade the wall of the mosquito's middle intestine, where they develop into oocysts, they grow, rupture and release sporozoites, which move to the salivary glands of the mosquito. Inoculation of sporozoites in a new human host perpetuates the life cycle of the parasite (Fig. 2) (LOURENÇO, 2018).

c) Vector/species transmitter Malaria

The mosquito *Anopheles darlingi* is one of the malaria vectors and the main species of transmission to Brazilian territory, which spreads through the bite of a female infected by the protozoan *Plasmodium*, which causes the disease. This species has wide geographical distribution in the Americas, extending from southern Mexico to northern Argentina, due to high humidity, the average temperature is between 20-30°C, so it is more likely to spread in the Amazonia. Under optimal conditions, the mosquito populations can reach a sufficient number of individuals to spread the Malaria disease (BARBOSA, 2014).

Only mosquito females feed on human blood tissue mandatory for egg development. Males feed only on plant saps and it has been not considered vectors disease.

Larvae develop in stagnant water and are more prevalent in periods of heavy rainfall, the species generally remain absent in regions with long periods of drought. However, even when present in low density, the species can maintain a high rate of Malaria transmission (BUENO, 2017).

d) Diagnosis and Treatment

The use of antimalarials intensified with the outbreak of SARS-CoV-2 and was used for the early treatment of the infection without any clinical proof of its efficacy. More recent studies prove that these drugs are not effective in treating this infection at any stage of its cycle (OMS, 2020). This fact brings concern due to the ability to acquire resistance to Chloroquine of some *Plasmodium* species, and this is no longer effective for reducing malaria viral load. Malaria is diagnosed from symptoms such as intermittent fevers, tremors, chills, sweating, severe headache, and especially yellowing in the mucous membranes.

For diagnosis, rapid tests are performed that are based on the capture of malaria protein derivatives (target antigens) by monoclonal antibodies reactive to

such antigens found in infected peripheral blood or complementary tests such as Polymerase Chain Reaction (PCR).

Patients with positive diagnoses, symptoms, and laboratory manifestations should be isolated and referred to emergency medical care to receive appropriate treatment (BRASIL, 2010). The laboratory manifestations are severe anemia, hypoglycemia, metabolic acidosis, renal failure, microvascular dysfunction, and hyperlactatemia.

Immediately after the diagnosis, start treatment with medicines made available by the Unified Health System (SUS), so-called antimalarials such as chloroquine, quinine, primaquine, doxycycline, and mefloquine. The dosage depends on the parasite species and patient age (MORENO et al., 2017). For *P. vivax* and *Plasmodium ovale* infection, the Ministry of Health (Brazil) recommends the use of chloroquine and primaquine while the treatment of *Plasmodium falciparum* infection non-severe is given with artemether + lumefantrine or artemether + mefloquine as the first choice and severe Malaria is Artemisinin derivatives. To *Plasmodium malariae* has only used chloroquine.

Drug treatment in severe cases has the purpose of interrupting schizogonia, which is responsible for the symptomatology in patient; such as destruction of the parasite in the tissue cycle (hypnozoites) of *P. vivax*, avoiding late relapses; interruption of transmission with the use of drugs that prevent the sexual development of the parasite (DE SOUZA et al., 2019).

According to the World Health Organization (2019), there is still no vaccine that generates a persistent immune response to Malaria and the substances currently available are drugs that losing their power leading to resistance of *Plasmodium* spp.

II. MATERIALS AND METHODS

The present work used the method based on the Experimental article Planning Factorial: A brief Review (OLIVEIRA et al., 2018), published in the journal International Journal of Advanced Engineering Research and Science (IJAERS).

To identify articles that talk about climate change in the incidence of Malaria from the uncontrolled reproduction of the propagation vector *A. darlingi*, searches were performed in the databases PubMed, ScienceDirect, Scielo, Google Scholar, Dialnet, WorldWideScience.org, Tandfonline, Dialnet, Microsoft Academic, DataSus and the Ministry of Agriculture (MAPA).

In the present study, the research strategy on the subject consisted of the use of keywords in English: 1. Climate Change in Brazil; 2. The life cycle of the *Anopheles darlingi* vector; 3. Impact of climate change on the *A. darlingi* life cycle; 4. Sensitive socioeconomic

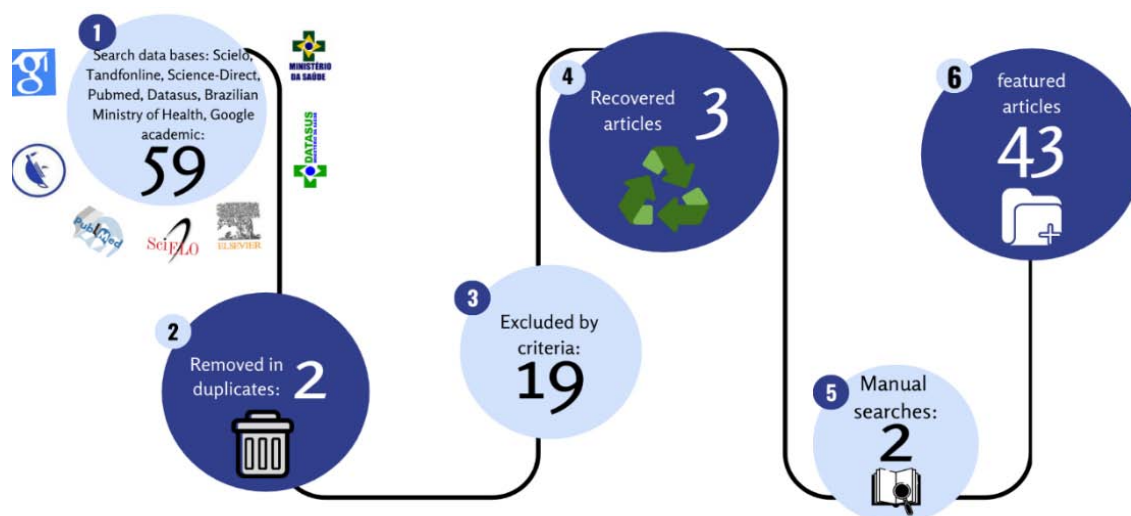
factors. The following filters have been added to the search in ScienceDirect: only journals; title, abstract; Keywords.

After consulting all the databases and using the search strategy adopted, repeated articles were identified between the different data sources. The criteria and filters for the inclusion of the articles in this work were: Original research articles that conceptualize the relationship between the effects of climate change on the incidence of Malaria through the vector *A. darlingi*, in different types of research fields, covering research completed in the present languages: Portuguese, English, and Spanish.

The papers taken from the study were grouped in the following order: repeated, irrelevant, other publication formats (edict, short communications, perspectives, letters), and other languages that were not well understood. Besides, manual searches were evaluated in bibliographic references of the review articles found with previously determined keywords.

III. DATABASE STRUCTURE

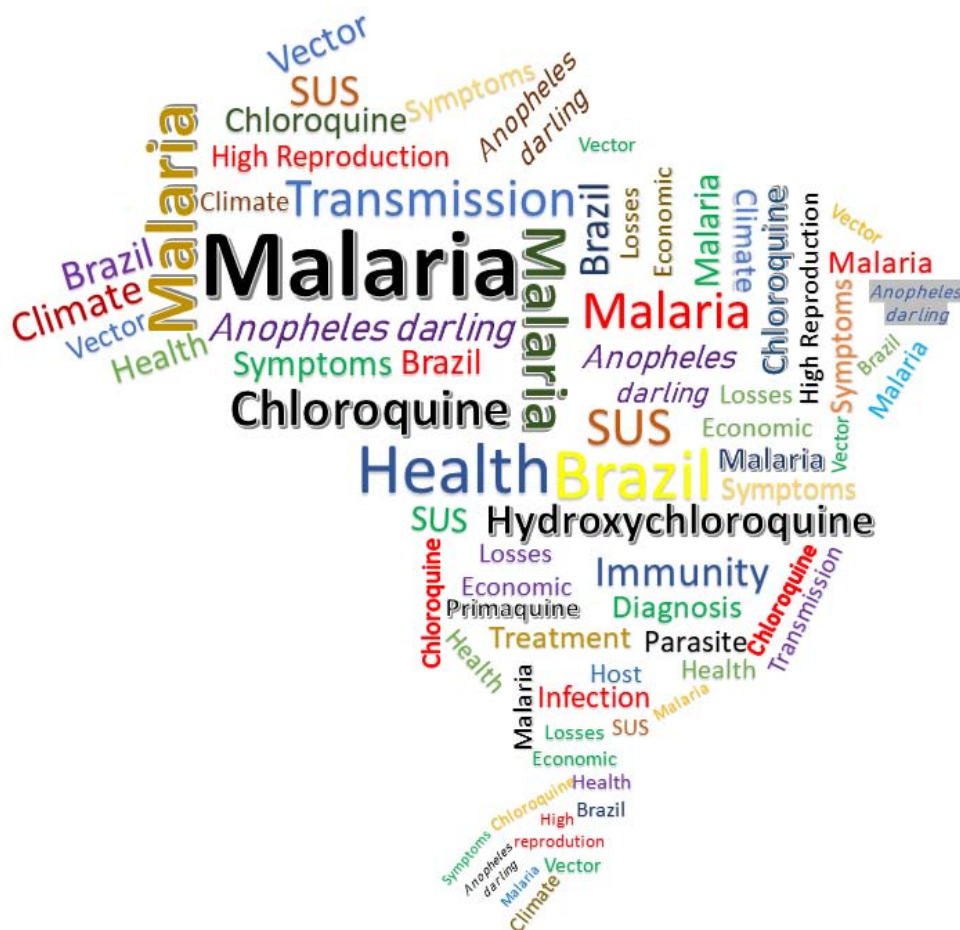
Further studies are needed to identify the endemic direction and malaria morbidity in the population. Therefore, because of the different searches in the databases, 55 articles were found that cover the theme addressed in this study. After the removal of the duplicate articles, the exclusion criteria were applied. Of the total of 50 articles studied, 19 of them were removed according to the criteria adopted. Two duplicate articles were excluded and three original research articles were retrieved. Through manual search were retrieved two more articles (Fig. 3).



Source: Prepared by the author (2020).

Figure 3: Flowchart of identification and selection of articles prepared by the authors, 2020.

Finally, through a word cloud was visually identified the keywords used to collect information in databases. Larger words indicate a higher incidence of Malaria according to the region where it is located and the lowest, addresses the lower incidence (Fig. 4).



Source: Prepared by the author (2020).

Figure 4: Keyword cloud produced by authors to elaborate on the work, 2020.

IV. RESULTS

Malaria infection rate not only depends on vector and parasite but also regional weather conditions, preventive care, and post-infection treatment. The incidence of the vector is characterized by several factors, such as biological, ecological, sociopolitical, cultural, and economic factors, the latter influencing health expenditures in Brazil concerning preventive measures of infection (SIQUEIRA et al., 2018).

a) *Economic losses caused by Malaria in Brazil*

The social and economic losses caused by Malaria affect pauperized populations, far from access to health services and living in precarious conditions of housing and basic sanitation. According to Brazil Communication Company - BCC (2019), the nine states that make up the Amazon have the Municipal Human Development Index (M-HDI) below 0.750 and that of Brazil 0.761. This index seeks to measure the health, education, and income of the population and express the "human development" of the region. At the economic level, Malaria is strongly linked to poverty, where cases occur predominantly in 80% of rural areas and 11% in mining and settlements, which are priority areas for Malaria because they are highly receptive (BRASIL, 2019).

The economic impact includes expenses with any health care, lost service days, loss of classes in the education system, as well as lower-income at work due to brain injuries, among others. Malaria Generates Poverty and Poverty Breeds Malaria (CARDONA-ARIAS, 2019).

In 2013, global spending on malaria intervention was around 2.6 billion. In 2015, the Pan American Health Organization had estimated health expenditures in the range of US\$ 5.1 billion. In Brazil, the total number of hospitalizations for Malaria from 1998 to 2005 generated a cost of R\$ 19 billion and an average cost of R\$ 161.52 per hospitalization. Hospitalizations for unspecified malaria cost R\$ 7.6 billion to the Brazilian Unified Health System (ROSSETO et al., 2013).

Currently, the economic burden of malaria epidemics remains unclear. Studies conducted in stable transmission areas have established that Malaria causes considerable losses for families in the form of income, treatment costs, loss of schooling, and decreased agricultural production (MOURÃO, 2018).

b) *Fifth IPCC Report*

The Intergovernmental Panel on Climate Change (IPCC) is the leading international body for the assessment of climate change. In 1988, through the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO), an agreement was established to which, these entities would provide the world with a clear scientific view of the

current state of knowledge about climate change and its potential environmental and socioeconomic impacts.

According to the fifth report released, the IPCC states that global warming is not a hoax, the atmosphere and oceans have warmed, glaciers have decreased and greenhouse gas concentrations are increasing considerably. The report highlights the ratio of greenhouse gases to the warming of the atmosphere and oceans, wherein 2011 the concentrations of the best-known gases, carbon dioxide (CO₂) and methane (CH₄), were 391 parts per million and 324 parts per billion, respectively.

The report also highlights the likely human influence on the warming of the atmosphere, especially about the emission of Greenhouse Gases (GHG) in the atmosphere, which reached the highest concentration in the last 800,000 years, as this is the main cause of the warming of the atmosphere, so to limit climate change, the report recommends drastically reducing greenhouse gas emissions (IPCC, 2008)

The forecast for the increase in temperature in the 21st century was made from four different scenarios, according to the concentrations of gases of the effect studies in the atmosphere. In the most optimistic scenario, the earth's surface temperature can increase by up to 0.7°C by the year 2100, in the most pessimistic scenario the temperature increase increases from 4°C for this same period (FERREIRA, 2017).

c) *Climate change forecast for Brazil*

According to the first National Assessment Report (NAR) published in 2015, the Brazilian panel on climate change was predicted for the Amazon biome, a 45% decrease in rainfall distribution for the region and an increase in temperature of up to 6°C by the year 2100 (PBMCI, 2014).

For the Caatinga biome, present in the Northeast region of Brazil, a decrease in rainfall distribution of up to 50% is also predicted, and an increase of up to 4.5°C by the end of the century. For the Cerrado biome, an increase in temperature is expected by the end of the century of up to 5.5°C and a decrease in precipitation of up to 45%. In the Pantanal biome, relatively is that the temperature will rise to 4.5°C, while the distribution of rainwater is reduced by up to 45%. These two biomes are most common in the Midwest and Southeast regions of the country. In the South region, a forecast was also made for the Pampa biome, where an increase of up to 3°C in temperature was projected by 2100, and different from the forecasts for out as regions predicted intensification of up to 40% in the distribution of rainfall in the region (FAUSTINO, 2016).

The projection for the amount of rainfall in the country will decrease in most regions. A fact associated with tropical ocean patterns, which according to projections will be abnormally warmer in the Pacific and

Atlantic, these patterns modify the wind regime, inhibiting the transport of moisture over tropical Brazil, inhibiting the formation of clouds (TAUIL, 1985).

d) *Impact of environmental changes on malaria transmissibility*

The Amazon region suffers annually from deforestation and burning for the expansion of agriculture, leading to environmental changes conducive to the emergence of new breeding sites for vectors transmitting Malaria (GIMING et al., 2002; VITOR et al., 2009; MUNGA et al., 2006; GIL et al., 2007).

Besides, the average variation in precipitation, temperature, and humidity in the previous two months also suggest increased malaria incidence rates (OESTERHOLT et al., 2006; GOMEZ-ELIPE et al., 2007; VASCONCELOS et al., 2006). The union of climate and environmental changes can alter the vector capacity due to increased survival of *A. darlingi* mosquitoes and consequently the population of these (MARTIN, 1995). Environmental changes together can trigger the emergence of new endemic areas and malaria transmission throughout Brazil (DA SILVA-NUNES, 2010).

e) *Malaria Incidence*

According to the Brazilian Ministry of Health, the North region has the highest number of reported cases

in the rest of the country. This notification in a regionalized manner occurs due to several factors influenced by the forest such: environmental conditions such as high temperature and humidity decrease the cyclic period of the virus, multiplying rapidly and increasing the transmissive capacity of the mosquito. Also, such conditions affect the reproductive factor of *A. darlingi* and thus the number of vectors grows alongside the viral load of *Plasmodium*, Demography, the North region is scanty populated and many people live scattered or in difficult-to-reach situations; resistance to treatment, in some localities there are strains of *Plasmodium*, resistant to Hydroxychloroquine, Chloroquine, Primaquina and other drugs already approved for reduction of viral load and mass treatment. Considering data collected by the Brazilian health information system (DataSus), the Amazon region has more than 80,000 reports of malaria cases for the period from January to March 2018 and 2019 alone (BRASIL – DataSus). The states of Amapá, Pará, and Roraima are endemic to Malaria in Brazil. The Tocantins has the lowest incidence.

In the extra-Amazonian region, notifications are extremely lower, with only 35 cases, also for the same period.

Table 5: Reports of malaria cases in Brazilian states.

UF	2018 (January to March)	2019 (January to March)
AC	9.787	3.334
AM	19.280	11.240
AP	2.726	2.879
MA	308	132
MT	186	81
PA	10.751	7.550
RO	1.684	1.970
RR	6.143	4.666
TO	12	3
Amazonian region	50.877	31.855
AL	2	0
BA	56	1
CE	10	0
DF	9	3
ES	9	1
GO	17	3
MG	9	0
MS	1	0
PB	3	0
PE	4	0
PI	4	0
PR	9	1
RJ	20	3
RN	4	0
RS	4	0
SE	7	1
SP	0	0
Extra-Amazon	31	4

Source: Prepared by the author (2020), adapted on Brazil Ministry of Health, (2020)

The Oswaldo Cruz Foundation (Fiocruz) is an institution that collects data and disseminates information about Brazilian health and social development and to the malaria problem, considers the Amazon region the most vulnerable in Brazil in terms of transmissibility of the disease and also for favorable environmental factors (Fiocruz, 2020). Socioeconomic factors in the region may also be directly related to the large difference of cases between the Amazon region and the extra-Amazon region since they are predictors of good or poor health conditions. Therefore, environmental conditions and socioeconomic factors

can be a sign of the increase or fall of notifications, hospitalizations, and deaths.

The difficulties faced in the Amazon region, such as: reaching places of difficult access and demographic dispersion hinder actions of prevention, diagnosis, and treatment of the disease, thus the lethality of the disease becomes increasingly increasing and the epidemic is installed. From January to June 2017 and 2018, the rate of hospitalizations showed a slight drop of 1% and deaths increased by 450%. (Table 6 and 7).

Table 6: Number of hospitalizations due to malaria cases in the Amazon and Extra-Amazon regions.

Amazon region	2017 (January to June)	2018 (January to June)	Difference %
Internações	735	726	-1%
Extra-Amazon	2017 (January to June)	2018 (January to June)	Difference %
Hospitalizations	84	109	+ 30%

Source: Prepared by the author (2020), adapted on Brazil Ministry of Health, (2020)

Table 7: The number of deaths due to malaria cases in the Amazon and Extra-Amazon regions.

Amazon region	2017 (January to February)	2018 (January to February)	Difference %
Deaths	2	11	+450%
Extra-Amazon	2017 (January to February)	2018 (January to February)	Difference %
Deaths	1	2	+100%

Source: Prepared by the author (2020), adapted on Brazil Ministry of Health, (2020)

According to tables 6 and 7, reports of malaria cases increased in extra-Amazonian regions by about 30% and deaths by 100%. These localities previously did not present ideal conditions for disease proliferation. However, global warming and the few malaria preventions and treatment policies favor the reproductive factor of *A. darlingi* and the spread of *Plasmodium* among people. In this way, new endemic areas arise.

If no measures are taken to reduce global warming, the world's tropical regions both endemic (Amazonian) and non-endemic (Extra-Amazonian) regions will suffer progressively with the increase in cases and deaths each year. Giving up efforts to contain Malaria can promote even greater economic losses than investing in prevention, control, and treatment measures (CARDONA-ARIAS, 2019).

For residents of regions with high endemic peak, it is recommended to adopt protective measures such as: not exposing yourself during sunrise and sunset, a period of high presence of the female *A. darlingi*, sleeping indoors and previously detested with insecticides based on pyrethrin, a substance that causes paralysis and death in insects. In general, it is not recommended to visit such regions, but if it is extremely necessary, important preventive measures

can be adopted, such as chemoprophylaxis consisting of using antimalarial drugs before visiting the site. The physician who prescribes antimalarial should consider the region and species of *Plasmodium*, which has a higher incidence, to avoid cases of viral resistance (MEIRELES, 2020).

For diagnosis, the World Health Organization (WHO) recommends the use of rapid diagnostic tests (RDT's), antigens produced by the parasite present in human blood. They are simple execution, high reliability, and the result is easy to interpret, being possible mass testing, to isolate and treat the infected. The treatment has advanced a lot over the years, mainly due to the high demand for new prophylactic drugs since *Plasmodium* sp., has high selection capacity and resistance to antimalarials widely used worldwide, such as Chloroquine, Hydroxychloroquine, and Primaquine. Currently, the treatment is performed with Artemisinin-based combination therapies (ACT's) that are extremely effective and eliminate much of the viral load present in the bloodstream, contributing to the reduction of hospitalizations and deaths (GENDROT, 2020).

In endemic countries, some people have already acquired immunity against the disease, so it is possible to develop a vaccine that generates an immune response and protects against the effects of

Malaria. For various diseases, induction of antibodies via vaccination is the best form of control, but for Malaria there is still no 100% effective vaccine. According to the WHO, in 2015 a protein-based recombinant vaccine capable of generating immune response was licensed, the popular name "RTS S/A S01" mosquitoes, the only one approved for malaria prevention. It induces antibodies that prevent *Plasmodium* from infecting the liver, has an average efficacy of up to 40%, and if administered early increases to 86% (BBC News, 2020).

V. CONCLUSION

Prevention by chemotherapy alone is insufficient to reduce cases and deaths from malaria, as *Plasmodium* can easily acquire resistance to these drugs. Constant investment in research is essential to design new antimalarial molecules and avoid resistance. A good antimalarial control program should gather environmental and epidemiological data, considering the Brazilian spatial heterogeneity and how the disease is transmitted, to identify endemic sites and administer the most effective antimalarial treatment.

The word cloud intuitively and appealingly identified the endemic areas most and least affected by Malaria in Brazil with the size of their font. Thus, being able to help the health system to guide the local population on the control, prevention, and antimalarial treatment present in the region.

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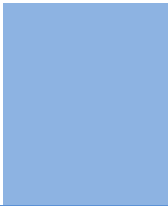
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TIPS FOR WRITING A GOOD QUALITY SOCIAL SCIENCE RESEARCH PAPER

Techniques for writing a good quality human social science research paper:

1. Choosing the topic: In most cases, the topic is selected by the interests of the author, but it can also be suggested by the guides. You can have several topics, and then judge which you are most comfortable with. This may be done by asking several questions of yourself, like "Will I be able to carry out a search in this area? Will I find all necessary resources to accomplish the search? Will I be able to find all information in this field area?" If the answer to this type of question is "yes," then you ought to choose that topic. In most cases, you may have to conduct surveys and visit several places. Also, you might have to do a lot of work to find all the rises and falls of the various data on that subject. Sometimes, detailed information plays a vital role, instead of short information. Evaluators are human: The first thing to remember is that evaluators are also human beings. They are not only meant for rejecting a paper. They are here to evaluate your paper. So present your best aspect.

2. Think like evaluators: If you are in confusion or getting demotivated because your paper may not be accepted by the evaluators, then think, and try to evaluate your paper like an evaluator. Try to understand what an evaluator wants in your research paper, and you will automatically have your answer. Make blueprints of paper: The outline is the plan or framework that will help you to arrange your thoughts. It will make your paper logical. But remember that all points of your outline must be related to the topic you have chosen.

3. Ask your guides: If you are having any difficulty with your research, then do not hesitate to share your difficulty with your guide (if you have one). They will surely help you out and resolve your doubts. If you can't clarify what exactly you require for your work, then ask your supervisor to help you with an alternative. He or she might also provide you with a list of essential readings.

4. Use of computer is recommended: As you are doing research in the field of human social science then this point is quite obvious. Use right software: Always use good quality software packages. If you are not capable of judging good software, then you can lose the quality of your paper unknowingly. There are various programs available to help you which you can get through the internet.

5. Use the internet for help: An excellent start for your paper is using Google. It is a wondrous search engine, where you can have your doubts resolved. You may also read some answers for the frequent question of how to write your research paper or find a model research paper. You can download books from the internet. If you have all the required books, place importance on reading, selecting, and analyzing the specified information. Then sketch out your research paper. Use big pictures: You may use encyclopedias like Wikipedia to get pictures with the best resolution. At Global Journals, you should strictly follow [here](#).



6. Bookmarks are useful: When you read any book or magazine, you generally use bookmarks, right? It is a good habit which helps to not lose your continuity. You should always use bookmarks while searching on the internet also, which will make your search easier.

7. Revise what you wrote: When you write anything, always read it, summarize it, and then finalize it.

8. Make every effort: Make every effort to mention what you are going to write in your paper. That means always have a good start. Try to mention everything in the introduction—what is the need for a particular research paper. Polish your work with good writing skills and always give an evaluator what he wants. Make backups: When you are going to do any important thing like making a research paper, you should always have backup copies of it either on your computer or on paper. This protects you from losing any portion of your important data.

9. Produce good diagrams of your own: Always try to include good charts or diagrams in your paper to improve quality. Using several unnecessary diagrams will degrade the quality of your paper by creating a hodgepodge. So always try to include diagrams which were made by you to improve the readability of your paper. Use of direct quotes: When you do research relevant to literature, history, or current affairs, then use of quotes becomes essential, but if the study is relevant to science, use of quotes is not preferable.

10. Use proper verb tense: Use proper verb tenses in your paper. Use past tense to present those events that have happened. Use present tense to indicate events that are going on. Use future tense to indicate events that will happen in the future. Use of wrong tenses will confuse the evaluator. Avoid sentences that are incomplete.

11. Pick a good study spot: Always try to pick a spot for your research which is quiet. Not every spot is good for studying.

12. Know what you know: Always try to know what you know by making objectives, otherwise you will be confused and unable to achieve your target.

13. Use good grammar: Always use good grammar and words that will have a positive impact on the evaluator; use of good vocabulary does not mean using tough words which the evaluator has to find in a dictionary. Do not fragment sentences. Eliminate one-word sentences. Do not ever use a big word when a smaller one would suffice.

Verbs have to be in agreement with their subjects. In a research paper, do not start sentences with conjunctions or finish them with prepositions. When writing formally, it is advisable to never split an infinitive because someone will (wrongly) complain. Avoid clichés like a disease. Always shun irritating alliteration. Use language which is simple and straightforward. Put together a neat summary.

14. Arrangement of information: Each section of the main body should start with an opening sentence, and there should be a changeover at the end of the section. Give only valid and powerful arguments for your topic. You may also maintain your arguments with records.

15. Never start at the last minute: Always allow enough time for research work. Leaving everything to the last minute will degrade your paper and spoil your work.

16. Multitasking in research is not good: Doing several things at the same time is a bad habit in the case of research activity. Research is an area where everything has a particular time slot. Divide your research work into parts, and do a particular part in a particular time slot.

17. Never copy others' work: Never copy others' work and give it your name because if the evaluator has seen it anywhere, you will be in trouble. Take proper rest and food: No matter how many hours you spend on your research activity, if you are not taking care of your health, then all your efforts will have been in vain. For quality research, take proper rest and food.

18. Go to seminars: Attend seminars if the topic is relevant to your research area. Utilize all your resources.

Refresh your mind after intervals: Try to give your mind a rest by listening to soft music or sleeping in intervals. This will also improve your memory. Acquire colleagues: Always try to acquire colleagues. No matter how sharp you are, if you acquire colleagues, they can give you ideas which will be helpful to your research.

19. Think technically: Always think technically. If anything happens, search for its reasons, benefits, and demerits. Think and then print: When you go to print your paper, check that tables are not split, headings are not detached from their descriptions, and page sequence is maintained.



20. Adding unnecessary information: Do not add unnecessary information like "I have used MS Excel to draw graphs." Irrelevant and inappropriate material is superfluous. Foreign terminology and phrases are not apropos. One should never take a broad view. Analogy is like feathers on a snake. Use words properly, regardless of how others use them. Remove quotations. Puns are for kids, not grunt readers. Never oversimplify: When adding material to your research paper, never go for oversimplification; this will definitely irritate the evaluator. Be specific. Never use rhythmic redundancies. Contractions shouldn't be used in a research paper. Comparisons are as terrible as clichés. Give up ampersands, abbreviations, and so on. Remove commas that are not necessary. Parenthetical words should be between brackets or commas. Understatement is always the best way to put forward earth-shaking thoughts. Give a detailed literary review.

21. Report concluded results: Use concluded results. From raw data, filter the results, and then conclude your studies based on measurements and observations taken. An appropriate number of decimal places should be used. Parenthetical remarks are prohibited here. Proofread carefully at the final stage. At the end, give an outline to your arguments. Spot perspectives of further study of the subject. Justify your conclusion at the bottom sufficiently, which will probably include examples.

22. Upon conclusion: Once you have concluded your research, the next most important step is to present your findings. Presentation is extremely important as it is the definite medium through which your research is going to be in print for the rest of the crowd. Care should be taken to categorize your thoughts well and present them in a logical and neat manner. A good quality research paper format is essential because it serves to highlight your research paper and bring to light all necessary aspects of your research.

INFORMAL GUIDELINES OF RESEARCH PAPER WRITING

Key points to remember:

- Submit all work in its final form.
- Write your paper in the form which is presented in the guidelines using the template.
- Please note the criteria peer reviewers will use for grading the final paper.

Final points:

One purpose of organizing a research paper is to let people interpret your efforts selectively. The journal requires the following sections, submitted in the order listed, with each section starting on a new page:

The introduction: This will be compiled from reference matter and reflect the design processes or outline of basis that directed you to make a study. As you carry out the process of study, the method and process section will be constructed like that. The results segment will show related statistics in nearly sequential order and direct reviewers to similar intellectual paths throughout the data that you gathered to carry out your study.

The discussion section:

This will provide understanding of the data and projections as to the implications of the results. The use of good quality references throughout the paper will give the effort trustworthiness by representing an alertness to prior workings.

Writing a research paper is not an easy job, no matter how trouble-free the actual research or concept. Practice, excellent preparation, and controlled record-keeping are the only means to make straightforward progression.

General style:

Specific editorial column necessities for compliance of a manuscript will always take over from directions in these general guidelines.

To make a paper clear: Adhere to recommended page limits.



Mistakes to avoid:

- Insertion of a title at the foot of a page with subsequent text on the next page.
- Separating a table, chart, or figure—confine each to a single page.
- Submitting a manuscript with pages out of sequence.
- In every section of your document, use standard writing style, including articles ("a" and "the").
- Keep paying attention to the topic of the paper.
- Use paragraphs to split each significant point (excluding the abstract).
- Align the primary line of each section.
- Present your points in sound order.
- Use present tense to report well-accepted matters.
- Use past tense to describe specific results.
- Do not use familiar wording; don't address the reviewer directly. Don't use slang or superlatives.
- Avoid use of extra pictures—include only those figures essential to presenting results.

Title page:

Choose a revealing title. It should be short and include the name(s) and address(es) of all authors. It should not have acronyms or abbreviations or exceed two printed lines.

Abstract: This summary should be two hundred words or less. It should clearly and briefly explain the key findings reported in the manuscript and must have precise statistics. It should not have acronyms or abbreviations. It should be logical in itself. Do not cite references at this point.

An abstract is a brief, distinct paragraph summary of finished work or work in development. In a minute or less, a reviewer can be taught the foundation behind the study, common approaches to the problem, relevant results, and significant conclusions or new questions.

Write your summary when your paper is completed because how can you write the summary of anything which is not yet written? Wealth of terminology is very essential in abstract. Use comprehensive sentences, and do not sacrifice readability for brevity; you can maintain it succinctly by phrasing sentences so that they provide more than a lone rationale. The author can at this moment go straight to shortening the outcome. Sum up the study with the subsequent elements in any summary. Try to limit the initial two items to no more than one line each.

Reason for writing the article—theory, overall issue, purpose.

- Fundamental goal.
- To-the-point depiction of the research.
- Consequences, including definite statistics—if the consequences are quantitative in nature, account for this; results of any numerical analysis should be reported. Significant conclusions or questions that emerge from the research.

Approach:

- Single section and succinct.
- An outline of the job done is always written in past tense.
- Concentrate on shortening results—limit background information to a verdict or two.
- Exact spelling, clarity of sentences and phrases, and appropriate reporting of quantities (proper units, important statistics) are just as significant in an abstract as they are anywhere else.

Introduction:

The introduction should "introduce" the manuscript. The reviewer should be presented with sufficient background information to be capable of comprehending and calculating the purpose of your study without having to refer to other works. The basis for the study should be offered. Give the most important references, but avoid making a comprehensive appraisal of the topic. Describe the problem visibly. If the problem is not acknowledged in a logical, reasonable way, the reviewer will give no attention to your results. Speak in common terms about techniques used to explain the problem, if needed, but do not present any particulars about the protocols here.



The following approach can create a valuable beginning:

- o Explain the value (significance) of the study.
- o Defend the model—why did you employ this particular system or method? What is its compensation? Remark upon its appropriateness from an abstract point of view as well as pointing out sensible reasons for using it.
- o Present a justification. State your particular theory(-ies) or aim(s), and describe the logic that led you to choose them.
- o Briefly explain the study's tentative purpose and how it meets the declared objectives.

Approach:

Use past tense except for when referring to recognized facts. After all, the manuscript will be submitted after the entire job is done. Sort out your thoughts; manufacture one key point for every section. If you make the four points listed above, you will need at least four paragraphs. Present surrounding information only when it is necessary to support a situation. The reviewer does not desire to read everything you know about a topic. Shape the theory specifically—do not take a broad view.

As always, give awareness to spelling, simplicity, and correctness of sentences and phrases.

Procedures (methods and materials):

This part is supposed to be the easiest to carve if you have good skills. A soundly written procedures segment allows a capable scientist to replicate your results. Present precise information about your supplies. The suppliers and clarity of reagents can be helpful bits of information. Present methods in sequential order, but linked methodologies can be grouped as a segment. Be concise when relating the protocols. Attempt to give the least amount of information that would permit another capable scientist to replicate your outcome, but be cautious that vital information is integrated. The use of subheadings is suggested and ought to be synchronized with the results section.

When a technique is used that has been well-described in another section, mention the specific item describing the way, but draw the basic principle while stating the situation. The purpose is to show all particular resources and broad procedures so that another person may use some or all of the methods in one more study or referee the scientific value of your work. It is not to be a step-by-step report of the whole thing you did, nor is a methods section a set of orders.

Materials:

Materials may be reported in part of a section or else they may be recognized along with your measures.

Methods:

- o Report the method and not the particulars of each process that engaged the same methodology.
- o Describe the method entirely.
- o To be succinct, present methods under headings dedicated to specific dealings or groups of measures.
- o Simplify—detail how procedures were completed, not how they were performed on a particular day.
- o If well-known procedures were used, account for the procedure by name, possibly with a reference, and that's all.

Approach:

It is embarrassing to use vigorous voice when documenting methods without using first person, which would focus the reviewer's interest on the researcher rather than the job. As a result, when writing up the methods, most authors use third person passive voice.

Use standard style in this and every other part of the paper—avoid familiar lists, and use full sentences.

What to keep away from:

- o Resources and methods are not a set of information.
- o Skip all descriptive information and surroundings—save it for the argument.
- o Leave out information that is immaterial to a third party.



Results:

The principle of a results segment is to present and demonstrate your conclusion. Create this part as entirely objective details of the outcome, and save all understanding for the discussion.

The page length of this segment is set by the sum and types of data to be reported. Use statistics and tables, if suitable, to present consequences most efficiently.

You must clearly differentiate material which would usually be incorporated in a study editorial from any unprocessed data or additional appendix matter that would not be available. In fact, such matters should not be submitted at all except if requested by the instructor.

Content:

- o Sum up your conclusions in text and demonstrate them, if suitable, with figures and tables.
- o In the manuscript, explain each of your consequences, and point the reader to remarks that are most appropriate.
- o Present a background, such as by describing the question that was addressed by creation of an exacting study.
- o Explain results of control experiments and give remarks that are not accessible in a prescribed figure or table, if appropriate.
- o Examine your data, then prepare the analyzed (transformed) data in the form of a figure (graph), table, or manuscript.

What to stay away from:

- o Do not discuss or infer your outcome, report surrounding information, or try to explain anything.
- o Do not include raw data or intermediate calculations in a research manuscript.
- o Do not present similar data more than once.
- o A manuscript should complement any figures or tables, not duplicate information.
- o Never confuse figures with tables—there is a difference.

Approach:

As always, use past tense when you submit your results, and put the whole thing in a reasonable order.

Put figures and tables, appropriately numbered, in order at the end of the report.

If you desire, you may place your figures and tables properly within the text of your results section.

Figures and tables:

If you put figures and tables at the end of some details, make certain that they are visibly distinguished from any attached appendix materials, such as raw facts. Whatever the position, each table must be titled, numbered one after the other, and include a heading. All figures and tables must be divided from the text.

Discussion:

The discussion is expected to be the trickiest segment to write. A lot of papers submitted to the journal are discarded based on problems with the discussion. There is no rule for how long an argument should be.

Position your understanding of the outcome visibly to lead the reviewer through your conclusions, and then finish the paper with a summing up of the implications of the study. The purpose here is to offer an understanding of your results and support all of your conclusions, using facts from your research and generally accepted information, if suitable. The implication of results should be fully described.

Infer your data in the conversation in suitable depth. This means that when you clarify an observable fact, you must explain mechanisms that may account for the observation. If your results vary from your prospect, make clear why that may have happened. If your results agree, then explain the theory that the proof supported. It is never suitable to just state that the data approved the prospect, and let it drop at that. Make a decision as to whether each premise is supported or discarded or if you cannot make a conclusion with assurance. Do not just dismiss a study or part of a study as "uncertain."



Research papers are not acknowledged if the work is imperfect. Draw what conclusions you can based upon the results that you have, and take care of the study as a finished work.

- You may propose future guidelines, such as how an experiment might be personalized to accomplish a new idea.
- Give details of all of your remarks as much as possible, focusing on mechanisms.
- Make a decision as to whether the tentative design sufficiently addressed the theory and whether or not it was correctly restricted. Try to present substitute explanations if they are sensible alternatives.
- One piece of research will not counter an overall question, so maintain the large picture in mind. Where do you go next? The best studies unlock new avenues of study. What questions remain?
- Recommendations for detailed papers will offer supplementary suggestions.

Approach:

When you refer to information, differentiate data generated by your own studies from other available information. Present work done by specific persons (including you) in past tense.

Describe generally acknowledged facts and main beliefs in present tense.

THE ADMINISTRATION RULES

Administration Rules to Be Strictly Followed before Submitting Your Research Paper to Global Journals Inc.

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Segment draft and final research paper: You have to strictly follow the template of a research paper, failing which your paper may get rejected. You are expected to write each part of the paper wholly on your own. The peer reviewers need to identify your own perspective of the concepts in your own terms. Please do not extract straight from any other source, and do not rephrase someone else's analysis. Do not allow anyone else to proofread your manuscript.

Written material: You may discuss this with your guides and key sources. Do not copy anyone else's paper, even if this is only imitation, otherwise it will be rejected on the grounds of plagiarism, which is illegal. Various methods to avoid plagiarism are strictly applied by us to every paper, and, if found guilty, you may be blacklisted, which could affect your career adversely. To guard yourself and others from possible illegal use, please do not permit anyone to use or even read your paper and file.



CRITERION FOR GRADING A RESEARCH PAPER (COMPILATION)
BY GLOBAL JOURNALS

Please note that following table is only a Grading of "Paper Compilation" and not on "Performed/Stated Research" whose grading solely depends on Individual Assigned Peer Reviewer and Editorial Board Member. These can be available only on request and after decision of Paper. This report will be the property of Global Journals

Topics	Grades		
	A-B	C-D	E-F
<i>Abstract</i>	Clear and concise with appropriate content, Correct format. 200 words or below	Unclear summary and no specific data, Incorrect form Above 200 words	No specific data with ambiguous information Above 250 words
<i>Introduction</i>	Containing all background details with clear goal and appropriate details, flow specification, no grammar and spelling mistake, well organized sentence and paragraph, reference cited	Unclear and confusing data, appropriate format, grammar and spelling errors with unorganized matter	Out of place depth and content, hazy format
<i>Methods and Procedures</i>	Clear and to the point with well arranged paragraph, precision and accuracy of facts and figures, well organized subheads	Difficult to comprehend with embarrassed text, too much explanation but completed	Incorrect and unorganized structure with hazy meaning
<i>Result</i>	Well organized, Clear and specific, Correct units with precision, correct data, well structuring of paragraph, no grammar and spelling mistake	Complete and embarrassed text, difficult to comprehend	Irregular format with wrong facts and figures
<i>Discussion</i>	Well organized, meaningful specification, sound conclusion, logical and concise explanation, highly structured paragraph reference cited	Wordy, unclear conclusion, spurious	Conclusion is not cited, unorganized, difficult to comprehend
<i>References</i>	Complete and correct format, well organized	Beside the point, Incomplete	Wrong format and structuring



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ISSN 975587

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