Terra – An AI-based Personalized Carbon Footprint and Offset Companion

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***Abstract*— Climate change is a global phenomenon characterized by long-term alterations in temperature and weather patterns, caused primarily by anthropogenic activities such as the combustion of fossil fuels, deforestation, and industrial processes. These activities have significantly increased atmospheric concentrations of greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), leading to undesirable effects with household and individual consumption being a major contributor to such emissions. However, these actions are often viewed in isolation and the cumulative effects of these actions are not understood by the general public, leading to rising consumerism trends and waste generation. This paper introduces a mobile application, Terra, that helps users become more aware of the effects of their consumption on the environment. The proposed application integrates advanced artificial intelligence, including Retrieval-Augmented Generation (RAG) with the Llama 3.2 3B Instruct model and SearXNG for web search, to provide personalized carbon emission tracking, eco-friendly consumption guidance, and engagement in verified carbon offset projects. The application also incorporates an OCR tool for detecting labels from user-captured grocery items, allowing users to make more sustainable consumption choices. By quantifying individual emissions and offering actionable insights, the application aims to foster sustainable practices and contribute to global environmental conservation efforts.**

***Index Terms*—Climate Change, Sustainability, Carbon Footprint, Large Language Models (LLMs), Retrieval Augmented Generation, Carbon Offsets**

I. Introduction

According to a study conducted by Weber et al. [1], it was concluded that it was psychologically difficult to gain a proper understanding of global phenomena like climate change because of three reasons, one of which is the psychological tendency to rely on personal experience, and to relate our acknowledgement of these phenomena to such personal experiences. In the light of this conclusion, individuals may not be able to corelate how their actions lead to negative environmental effects.

However, according to a study conducted by Hertwich et al. [2], households and individuals are responsible for about 72% of GHG emissions globally, and thus play a critical role in mitigating phenomena such as climate change. In a society with deep individualism and massive consumerism trends, it is difficult to see the value of small individual actions for climate change mitigation, as they are viewed in isolation, and not as part of a complete system. Often, individual actions represented in a larger scale, leading to misconceptions and lack of awareness.

In this paper, we propose Terra, an Artificial Intelligence (AI)-based personalized carbon footprint and offset companion, as a method to mitigate the issue proposed, by allowing users to quantify the effects of their consumption and waste generation by tracking their carbon footprint and making more sustainable choices through actionable insights derived from AI assistants. Through this mobile application, users can quantify the effects of their choices and take suitable steps to offset their carbon footprint, by through household initiatives, or by financing verified carbon offset projects.

By integrating data from various sources, such as streaming times, transportation modes, and energy usage, the system offers a comprehensive view of an individual's environmental impact. It also includes mechanisms for the calculation, storage, and retrieval of carbon footprint data related to transportation, food, and streaming. The mobile assistant also leverages Retrieval-Augmented Generation (RAG) with the Llama 3.23B Instruct model and SearXNG for web search, to provide personalized recommendations based on user behavior and preferences. The primary objective is to create a user-friendly platform that not only quantifies emissions but also educates users on the environmental consequences of their actions. At present, the application derives focuses on the average Indian citizen and their activities, but holds immense scope to be extended to a globally acceptable method in the future.

II. Literature Survey and Related Work

In order to get a broader understanding of how individual activities impact the environment, various literature was reviewed. Ivanova et al. [3] conducted an environmental impact assessment of household consumption. The study highlighted the importance of environmental pressure arising from households with their consumption contributing to more than 60% of global GHG emissions and between 50% and 80% of total land, material, and water use.

Lee et al. [4] studied the household carbon footprints 623 districts in India, based on micro consumption data from 203,313 households and concluded that household carbon footprints in Indian low- and medium-level expenditure households are primarily driven by electricity consumption (mean = 0.19 ton CO2/capita), food consumption (mean = 0.12 ton CO2/capita) and consumables consumption (mean = 0.07 ton CO2/capita).

Tilman et al. [5] assessed the environmental consequences of food production systems found that animal-based foods (e.g., beef, lamb, pork) have significantly higher environmental footprints compared to plant-based foods and that a shift towards plant-based diets was found to substantially reduce environmental impacts, including reductions in land use, water consumption, and greenhouse gas emissions.

Pathak et al. [6] calculated carbon footprint of specifically Indian food consumption and estimated GHG emission at current and projected levels of food consumption in India. It was concluded that for a balanced diet (vegetarian), an adult Indian consumed 1165 g food per day and emitted 723.7 g CO_2eq. GHG per day, whereas a non-vegetarian diet emitted around 1031 g of CO_2eq. GHG per day.

Kumar et al. [7] analyzed the application of clean development mechanisms in the road transportation sector in Delhi, India, with a focus on reducing greenhouse gas emissions. The study also calculated various per day emissions for various categories of vehicles in India.

Batmunkh et al. [8] estimated the carbon footprint of popular social media platforms by analyzing their energy consumption and environmental impact and concluded significant variation in the carbon footprints of social media platforms, with larger platforms having higher emissions due to their extensive data centres and user bases.

Following the understanding of the potential effects of individual actions on the environment, related work was and their potential outcomes were reviewed. Hemanth et al. [9] developed a web-based platform to encourage individuals to adopt environmentally friendly practices with features including a sustainability rating system, carbon footprint calculator, and AI-powered chatbot (EcoBot). The platform demonstrated high usability and effectiveness in promoting sustainable practices among diverse users. The platform's current design faced challenges in handling a large, global user base without additional optimizations.

Dash et al. [10] developed and implemented effective strategies for reducing carbon footprints across several fields, such as transportation, appliance usage, and everyday human activities. AI was integrated for increasing user awareness. However, the accuracy of the carbon footprint calculations is contingent upon user-provided data, which may be prone to errors or inconsistencies and currently monitors weekly advancements and offers restricted resources for knowledge acquisition.

There does exist, however, a global need for systems such as the one proposed, with users showing high inclination towards its large-scale adoption. Rosenbusch et al. [11] examined user requirements for a carbon footprint tracker in an online study with 249 participants and a result, provided design features for tracking apps. Participants expressed a strong wish to deepen their understanding of their individual carbon footprint but the perceived literacy in terms of the CO2 footprint is rather low despite the high interest in the topic in the sample of participants.

Several works on RAG-based techniques were also reviewed. Xie et al. [12] proposed a new approach called WeKnow-RAG, integrating Web search and Knowledge Graphs into a RAG system to prevent phantom responses. Experimental results demonstrated significant improvements in factual accuracy and reasoning capabilities, with reduced hallucinations across domains.

Bayarri-Planas et al. [13] investigated the use Large Language Models (LLMs) in healthcare by integrating context retrieval systems to improve factual accuracy and reliability. The study concluded that the optimized retrieval system significantly boosts accuracy for smaller models but faced challenges in scaling open-ended question performance, particularly with verbose databases, and lacks generalization across diverse non-medical domains.

As a result of the literature survey, it was concluded that there exists a significant impact household and individual activities on climate change. These impacts are quantifiable and globally, users do express interest and inclination towards adopting systems that allow for mitigation activities. However, present solutions are not are robust or diverse, and miss out on key factors. In the next section, the methodology for building the proposed system is discussed, with the intention of improving on the shortfalls identified.

III. METHODOLOGY

This section details the methodology followed in creating the various modules of the application.

A. Carbon Footprint Tracker

The application tracks a user's carbon footprint in three categories namely, transport, food and streaming. Users can choose to track their footprint in each of these categories using fixed formulae.

For transport, various modes were provided to the user including 'car', 'bus', 'metro', etc. . The user was also required to enter the start and end location for each travel in the format 'Town/City, State, Country'. The locations were translated into latitude and longitude using the geocoding API from Geoapify. The coordinated were then used to calculate the distances between the two points, using the geolocator Flutter package. For each user entry, based on the CO_2 emission info per passenger per km for each type of transport and the distance between the locations travelled, the carbon emission was calculated and stored in a Firestore database.

For food, various meal options were provided such as 'rice-based vegetarian meal' or 'wheat-based non-vegetarian meal (chicken)'. The user could select the most appropriate meal type and the emission would be calculated according to the values obtained through the literature survey.

For streaming, users were required to enter the number of hours they used a streaming platform such as Netflix, and emissions factors were multiplied by the number of hours to get the emissions. All functions to calculate these emissions were implemented in Dart and accessed as through the Flutter backend. The emissions once calculated are stored in the Firestore backend database. Figure 1 demonstrates the workflow for this module.

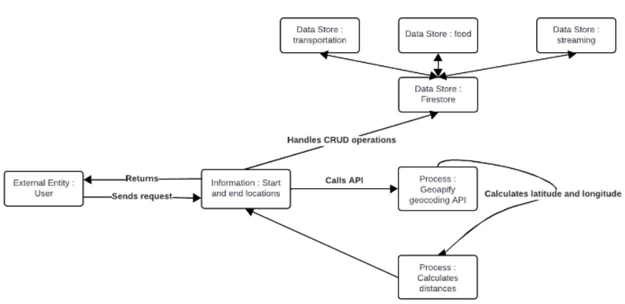

Figure 1

B. Carbon Offset and Climate Financing

Through this module, users are provided insights into how to offset their carbon footprint. Users are given the option to either offset their carbon individually by activities like tree planting or waste recycling, or to donate to carbon credit and offset projects.

C. AI-powered Eco-shopping and Waste Assistant

This module of the system is a Flask-based API designed to assist users in making eco-friendly shopping decisions and optimizing waste management through real-time web scraping and AI-driven recommendations. Users can input product names manually or upload images of product labels. The optical character recognition (OCR) processing module then extracts text from images using EasyOCR to identify product names. The web scraping module retrieves real-time Eco-Score information from the OpenFoodFacts database. The system queries OpenFoodFacts to fetch the Eco-Score of the identified product. The scraping process follows these steps –

- Perform an HTTP request to OpenFoodFacts, searching for the product name.
- Parse the response to extract product URLs based on user interaction frequency (sorted by clicks).
- Retrieve the product page and extract the Eco-Score using regular expressions.
- If an Eco-Score is found, return it; otherwise, provide a default response.

The AI module provides suggestions for both shopping alternatives and recycling methods. Shopping recommendations are provided for the user based on the product they entered to generate alternative eco-friendly homemade recipes as well as alternate brand recommendations. The assistant can also provide recycling ideas and environmentally safe disposal methods using another AI-generated prompt. The AI assistant is a RAG-based system and uses data fetched from the Internet to prevent hallucinations. The system retrieves Internet search information based on a local instance of SearXNG. The search information is filtered and context is extracted. The system then queries a local Ollama model instance via an API, passing the extracted context and product name to generate personalized recommendations. The same is followed for the eco-recycling assistant. The API endpoint handles requests and responses, providing structured output in JSON format, for its integration with the rest of the application. Figure 2 provides the workflow for this module

IV. RESULTS AND DISCUSSIONS

In this section, the frontend and backend integrations are discussed. In order to access the application, the user has to authenticated. This authentication process is done using the Firebase authentication feature, where users can log in using

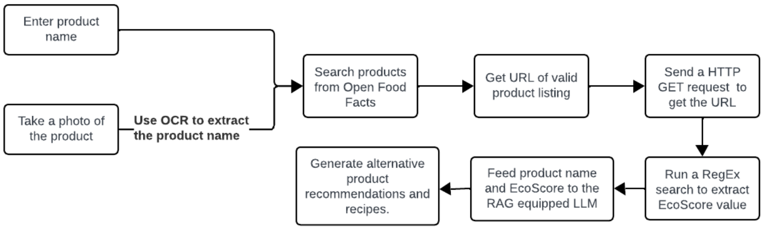

Figure 2

their email. The authenticated user can then access their dashboard, where their monthly target is displayed, along with their current emissions status. Users are given the option to either set a new monthly budget, view their previous emission stats or logout. The screen in shown in Figure 3. Once logged in the user can also visit the homepage where the various modules are integrated.

A. Carbon Footprint Tracker Integration

The module is integrated with the frontend as shown in Figure 4. The user can choose to log any of the given emission types. Figure 5 shows the transport emissions page, Figure 6 shows the food emissions page and Figure 7 shows the streaming emissions page. Once the user enters the required information, the calculations are performed at the backend and the data is stored in the Firestore database with unique documents for each user.

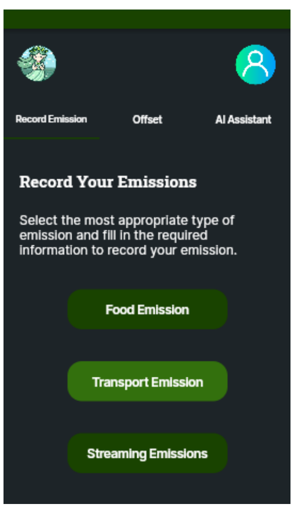

Figure 4

B. Carbon Footprint Tracker Integration

The user has the option to either donate to verified carbon offset projects or conduct household activities like plant trees or recycle waste. Figure 8 shows the module integrated with the frontend.

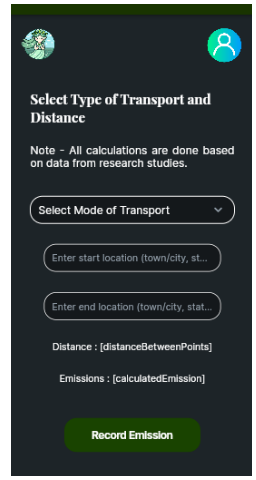

Figure 5

Figure 6

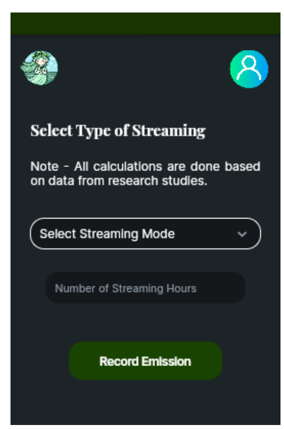

Figure 7

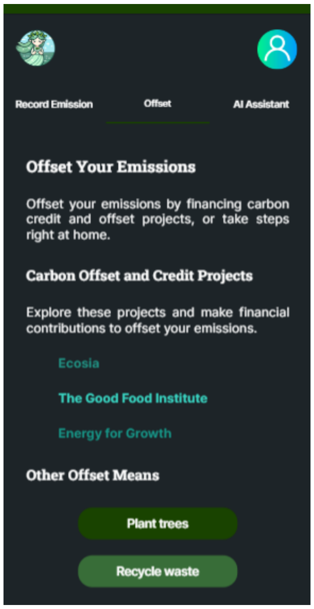

Figure 8

V. Conclusion

The proposed AI-based mobile application, Terra, presents a novel approach to quantifying and mitigating individual carbon footprints through intelligent tracking, AI-driven recommendations, and climate financing options. By integrating advanced Retrieval-Augmented Generation (RAG) with the Llama 3.2 3B Instruct model and leveraging real-time web searches via SearXNG, the system provides accurate, context-aware insights to users. The inclusion of an OCR-powered eco-shopping and waste assistant further enhances user engagement by enabling informed decision-making in daily consumption patterns. Additionally, the carbon footprint tracking module offers a structured methodology for estimating emissions from transportation, food consumption, and digital streaming activities, thereby providing an overall view of an individual's environmental impact.

While the current implementation is optimized for the Indian demographic, the system holds potential for adaptation across diverse geographic regions with the incorporation of localized emission factors. Future enhancements may include the integration of additional environmental impact categories, real-time emissions tracking, and machine learning-based predictive analytics to further refine recommendations. By fostering awareness and enabling actionable interventions, Terra serves as a step toward scalable, AI-driven climate solutions that empower individuals to contribute meaningfully to global sustainability efforts.

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