

অ	আ	ই	ই	উ	ঊ	এ	-	ঐ	ও	ঔ
o	a	i	i	u	oo	e	ø	ai	o	au
[ɔ]	[ə]	[i]	[i]	[u]	[u̯]	[e]	[ø̯]	[ai]	[o]	[au]
প	পা	পি	পী	পু	পূ	পে	পৈ	পৈ	পৈ	পো
po	pa	pi	pi	pu	poo	pe	poi	pai	poi	poo
ক	খ	গ	ঙ	চ	জ	ট	ঠ	ঢ	ত	
ka	kha	ga	ঙ	ca	za	la	da	ra	ta	
[k̥ɔ]	[k̥ə]	[g̥]	[g̥]	[z̥ɔ]	[z̥ə]	[t̥ə]	[d̥ə]	[r̥ə]	[t̥ə]	[d̥ə]
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## FUNDAMENTALS OF SPEECH PROCESSING ASSIGNMENT

# *Survey and Analysis of the Vowels Available in the Bodo Language*

*Preparation of the Vowel Chart*

Detailed Report on Bodo Language  
Survey and Analysis

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The Bodo language, belonging to the Tibeto-Burman language family, is one of the recognized scheduled languages of India, predominantly spoken in Assam and the northeastern region of the country. Bodo possesses a rich phonetic and phonological structure, making it an interesting subject for linguistic study.

## ***Historical Background***

The roots of the Bodo language trace back centuries, with the Bodo people historically residing in the Brahmaputra valley. The language represents one of the earliest settlements of the Tibeto-Burman speech communities in India. Traditionally, Bodo was an oral language with a rich tradition of folklore, songs, and oral histories. The introduction of the Roman script during the British colonial era marked the beginning of written documentation for Bodo. Later, the Assamese and Devanagari scripts were also employed. Since the 1960s, Devanagari has been officially adopted for its written form, which facilitated its use in education, literature, and administration.

## ***Linguistic Features***

The Bodo language is characterized by several distinct linguistic features, encompassing phonetics, phonology, morphology, syntax, and semantics. These features make Bodo an interesting subject for linguistic studies.

**Tone:** Bodo is a *tonal language*, and tonal variation is used to distinguish lexical or grammatical meanings. **High, mid, and low tones are observed**, which add complexity to its phonological system.

**Morphology:** Bodo is an *agglutinative language* where morphemes are attached to root words to indicate grammatical relationships.

- Prefixes and suffixes are commonly used, and inflectional morphology is more prevalent than derivational morphology.
- Verbs are marked for tense, aspect, mood, and negation. Nouns are inflected for case and number.

**Syntax:** The basic word order in Bodo is ***Subject-Object-Verb (SOV)***, which is typical of Tibeto-Burman languages.

- ***Postpositions, rather than prepositions***, are used to indicate relationships between words.
- Bodo employs relative clauses and exhibits a rich system of conjunctions to connect sentences and phrases.

**Semantics and Pragmatics:** Bodo semantics are deeply rooted in its cultural and environmental context. Many words and expressions reflect the agrarian lifestyle and the natural surroundings of the Bodo people. Pragmatic elements such as politeness, respect, and kinship terms are intricately woven into the language.

This project aimed to analyze the formant frequencies of vowels in the Bodo language through an acoustic study involving a controlled set of sentences spoken by native speakers.

## ***Objectives of the Survey***

The primary keynotes of this study were:

- To collect speech samples from native Bodo speakers.
- To annotate the speech data to identify vowel segments.
- To extract the first three formants (F1, F2, and F3) of each vowel segment.
- To analyze and visualize vowel formants through F1 vs. F2 plots.
- To study inter-speaker and gender-based variations in vowel articulation.

## ***Methodology***

The outline steps of the followed procedure during the survey include:

- Data Import: Automated loading of speech recordings into Praat.
- Annotation: Assisted annotation using pre-defined time intervals for vowel detection.
- Formant Extraction: Scripts to extract F1, F2, and F3 values and save them in a tabular format.
- Graphing: F1 vs. F2 graphs were plotted using a combination of Praat and external plotting tools like Python (Matplotlib).

### ***1. Participants***

- Speakers: 4 native Bodo speakers (2 males and 2 females).
  - **2 females:**
    - *Isu Basumatary*
    - *Age: 26*
    - *Place of Origins: Udalgori*

- **Kabita Boro**
  - **Age: 27**
  - **Place of Origins: Chirang**
- **2 males:**
  - **Brihem Basumatary**
    - **Age: 21**
    - **Place of Origins: Kokrajhar**
  - **Gyanjyoti Brahma**
    - **Age: 21**
    - **Place of Origins: Baksa**
- Recording Setup: Each speaker was instructed to pronounce 30 Bodo sentences, repeating each sentence three times.

## **2. Data Collection**

- Tool Used: The speech samples were recorded and analyzed using the **Praat** software.
- Environment: Recordings were conducted in a quiet setting to minimize background noise.
- Collected Data: Our data comprises **30 Bodo sentences – each spoken 3 times by each of the speakers/participants.**

*Sentence in Bodo    Pronunciation in English    Meaning in English*

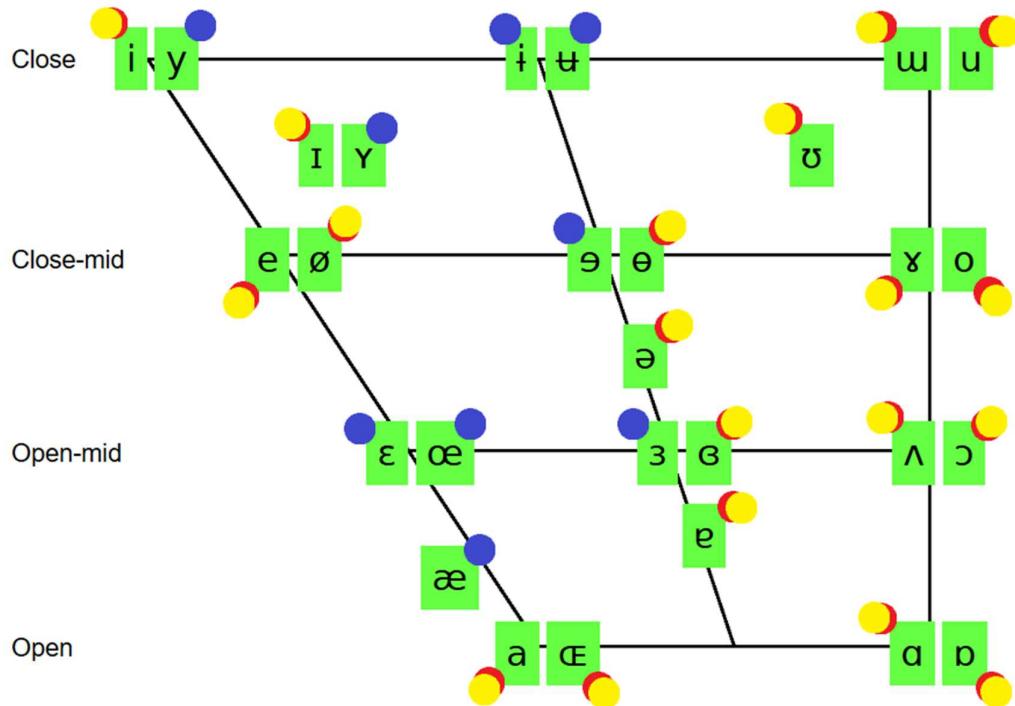
খুলুংবি	khulumbai	Namaste
মা খোবোৰ( খোউৱা)	Ma khobor	How are you
মা খালামদ্বো	Ma khalamdwng	What are you doing
নোঁনী বোইসো আ বেসেবাং	Nwngi bwisw aa besebang	How old are you
নোঁ অবেহানী	Nwng Bohani	Where are you from
অৰেহণাই থাঁনা	Boha tangnw	Where are you going

नों अबहै थाय	Nwng Boha thayw	Where do you live
नोंनि मुं आ मा	Nwngi mung ah maa	What is your name
आंनि मुं आ आंसुमान	angni mung aa Angshuman	My name is Angshuman
आं टेजपुर नि	ang tezpur nhi	I am from Tezpur
आंहा सासे आबो दं	Angha sase abo dong	I have an elder sister
आंहा सासे आदा दं	Angha sase ada dong	I have an elder brother
आं बेरायनो जोबोड मोजा मोनो	ang berainw jwbwd mwjang mwnw	I love to travel a lot
नों बेरायनो मोजां मोना नामा	nwng berainw mwjang mwnw nama	Do you like to travel
इंखां आम जाबाय नामा	wngkham jabai na	Have you had your meal
आं थांनोसाई	Ang thangnswi	I am going
नोंनि रुम खौ साफा खालाम	nwngni room kou saf a khalam	Clean your room
आं टेजपुर अो थांबै थादो	Ang tezpur ao thangbai thadwng	I am going to Tezpur
आं नोंखौ मोजां मोनो	Ang nwngkou mwjang mwnw	I love you
आं गोदान बाइक बाइबाय	Ang gwdan bike baibai	I bought a bike
नों माबोरै दं	Nwng marwi dong	How are you
दिनै बेटारआ मेजां	dnwi bwthwr aa mwjang	Today weather is good
क्लास आ खइटायो	class aa koitayao	What time is our class
गाबोन बारैहोइसुइ थो	gabwn beraihwiswi tho	Tomorrow let's go on a trip
मा उनक्रि जानो	ma wngkri janw	What curry do you wanna have

ବେହାଗ୍ରାୟାକ ଜିବୋ ଦଂ	bwi hagra yao jibwo dong	There's a snake in that grass
ମା ଖାଲାମଦୋ	ma kalamdwng	What are you doing?
ବେସଟିହ ନାମା ଦିନେ ମେନାୟାକ ଗେଜନ୍ୟୋ	bestoh nama dnwi mwnayao	Are you busy tonight?
ମା ଜାଖୋ	gwjwnthwng	Thank you
ମା ଜାଦୋ	ma jakw	What happened
	majadg	What are you eating

### 3. Annotation

- Speech recordings were annotated *manually* to mark the vowel segments.
- Annotations revealed the following vowels to be prevalent in the Bodo language
  - Only the ones marked blue are absent.



#### **4. Formant Extraction**

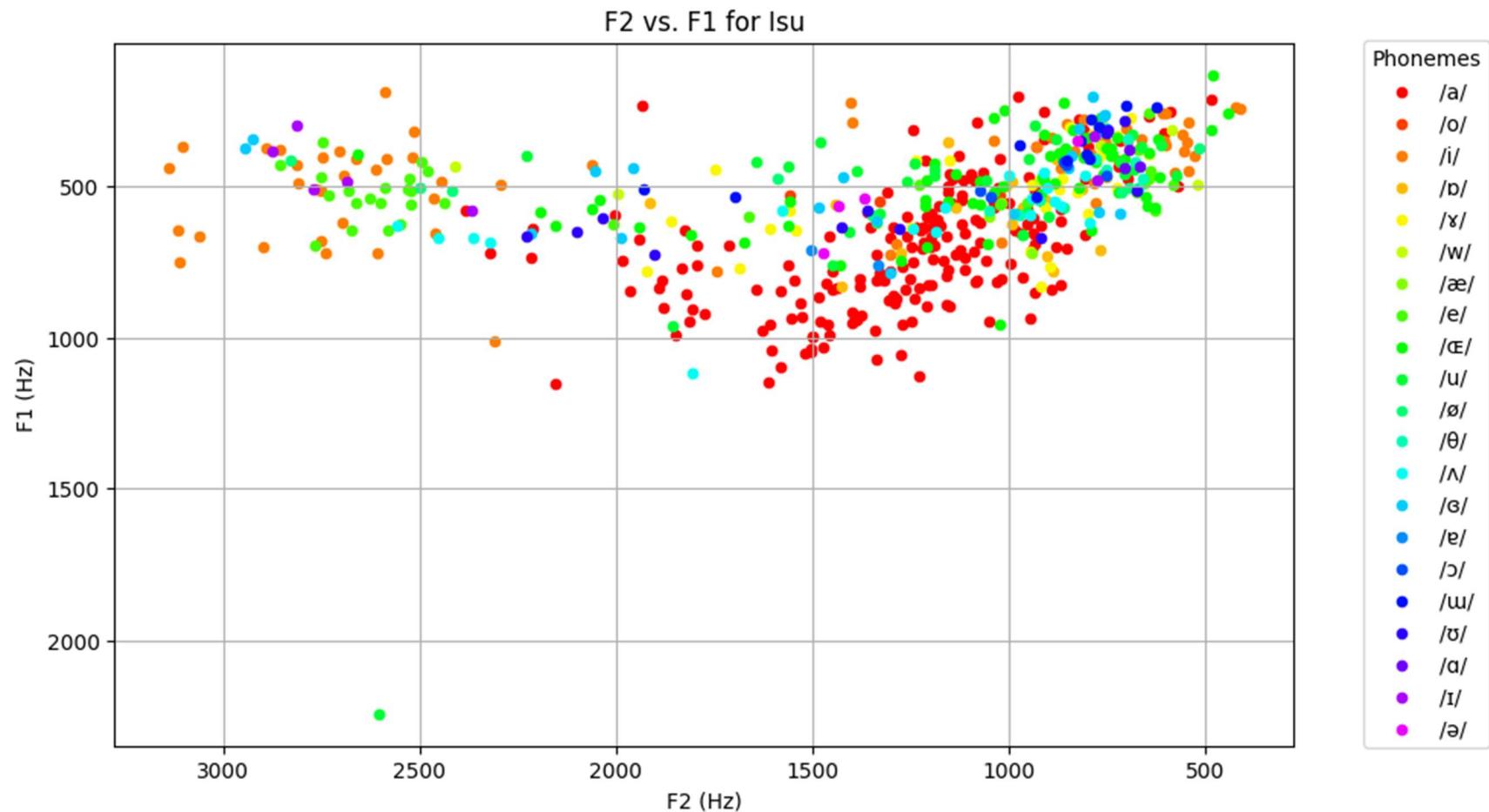
- For each vowel segment, the first three formants (F1, F2, and F3) were extracted using *Praat script*.
- Formants were averaged across repetitions for consistency.

#### **5. Graphical Analysis**

A series of F1 vs. F2 plots were generated to visualize the vowel space. The following comparisons were made:

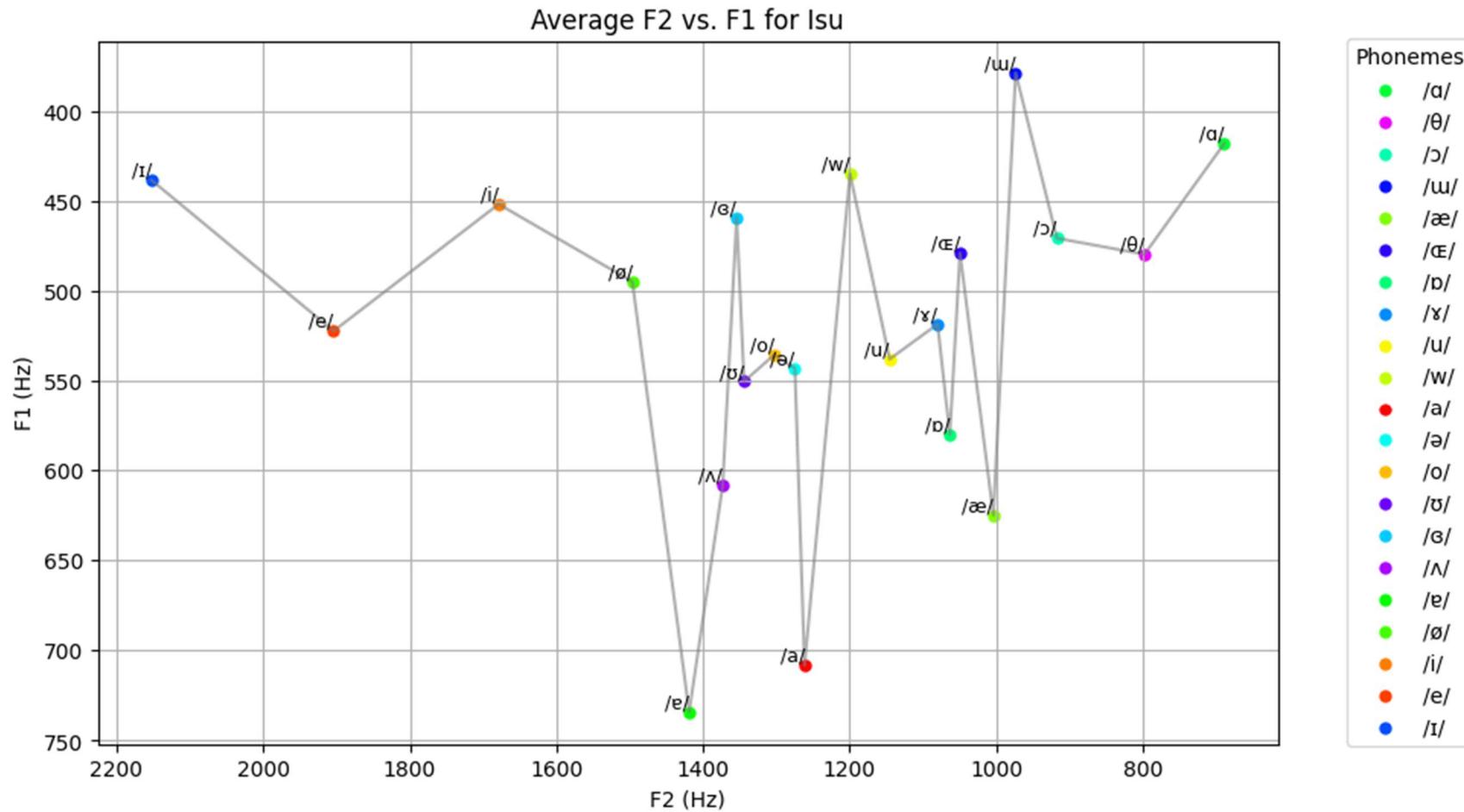
- Individual vowels spoken by each speaker.
  - Each speaker's vowel space was mapped using F1 vs. F2 graphs.
  - Observations included distinct clustering of vowels based on their phonetic properties and inter-speaker variability.
- Average formants for each vowel per speaker.
  - Averaging revealed patterns of vowel articulation that were consistent within the speakers.
  - Male speakers exhibited slightly lower formant frequencies due to differences in vocal tract length.
- All speakers' individual vowel plots.
- All speakers' average vowel plots.
  - Individual and averaged plots across all speakers provided insights into general trends in vowel articulation in Bodo.
  - Cross-speaker variation highlighted the phonetic richness of the language.
- Comparison between vowels spoken by the two female speakers.
- Comparison between average vowels spoken by the two female speakers.
- Comparison between vowels spoken by the two male speakers.
- Comparison between average vowels spoken by the two male speakers.
- Gender-based comparison (male vs. female).
  - Female speakers showed higher F1 and F2 values compared to male speakers, reflecting anatomical differences in vocal tracts.
  - Consistent vowel spaces were observed within each gender group.
- Average vowel comparison across genders.

## *Isu Basumatary:*



Distribution Range:

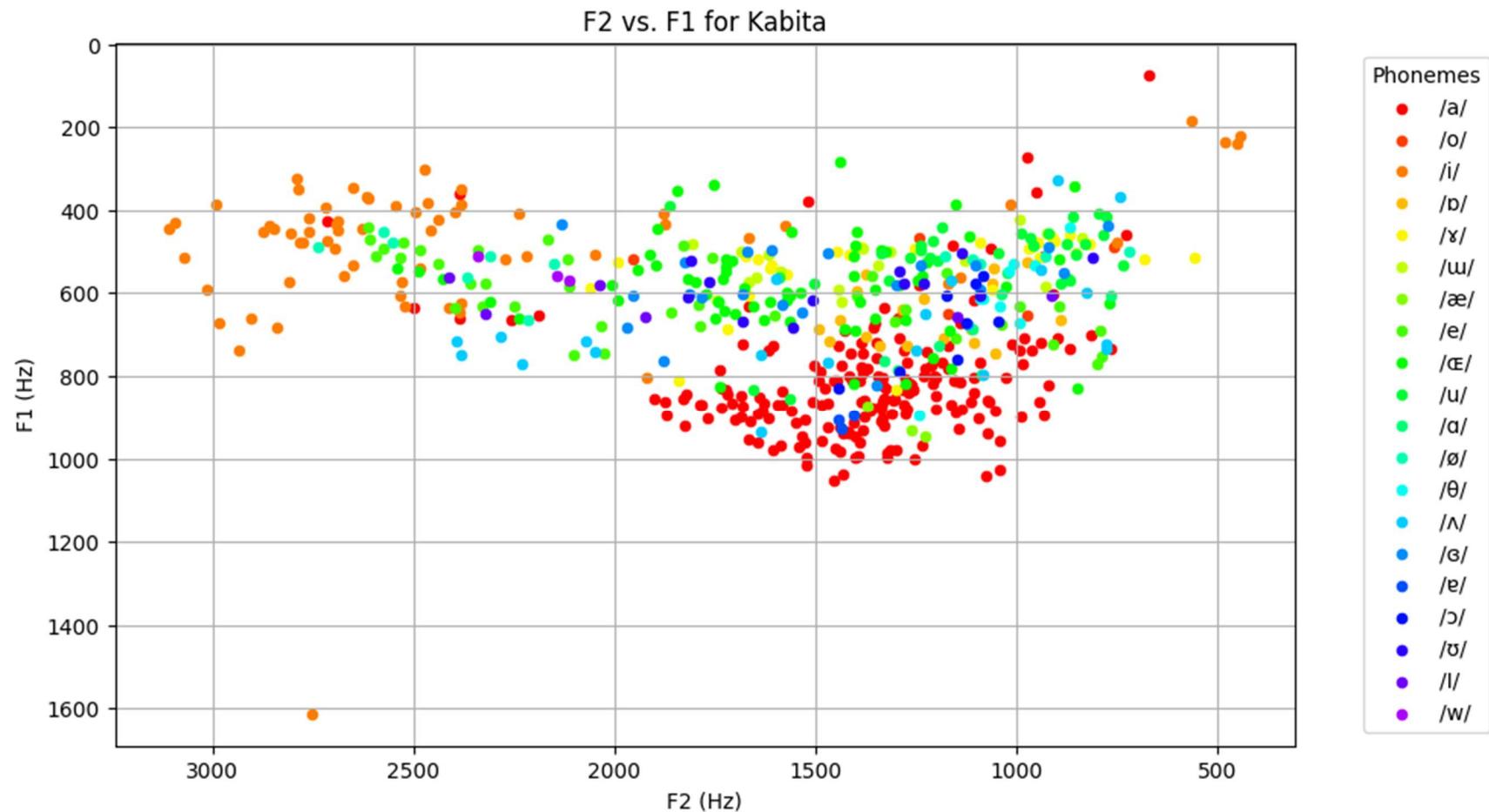
- The **F1** values range from about **300 Hz to 2000 Hz**, indicating a mix of open and close vowels.
- The **F2** values range from **500 Hz to 3000 Hz**, covering both back and front vowels.



The vowels show distinct clusters, reflecting their phonetic properties:

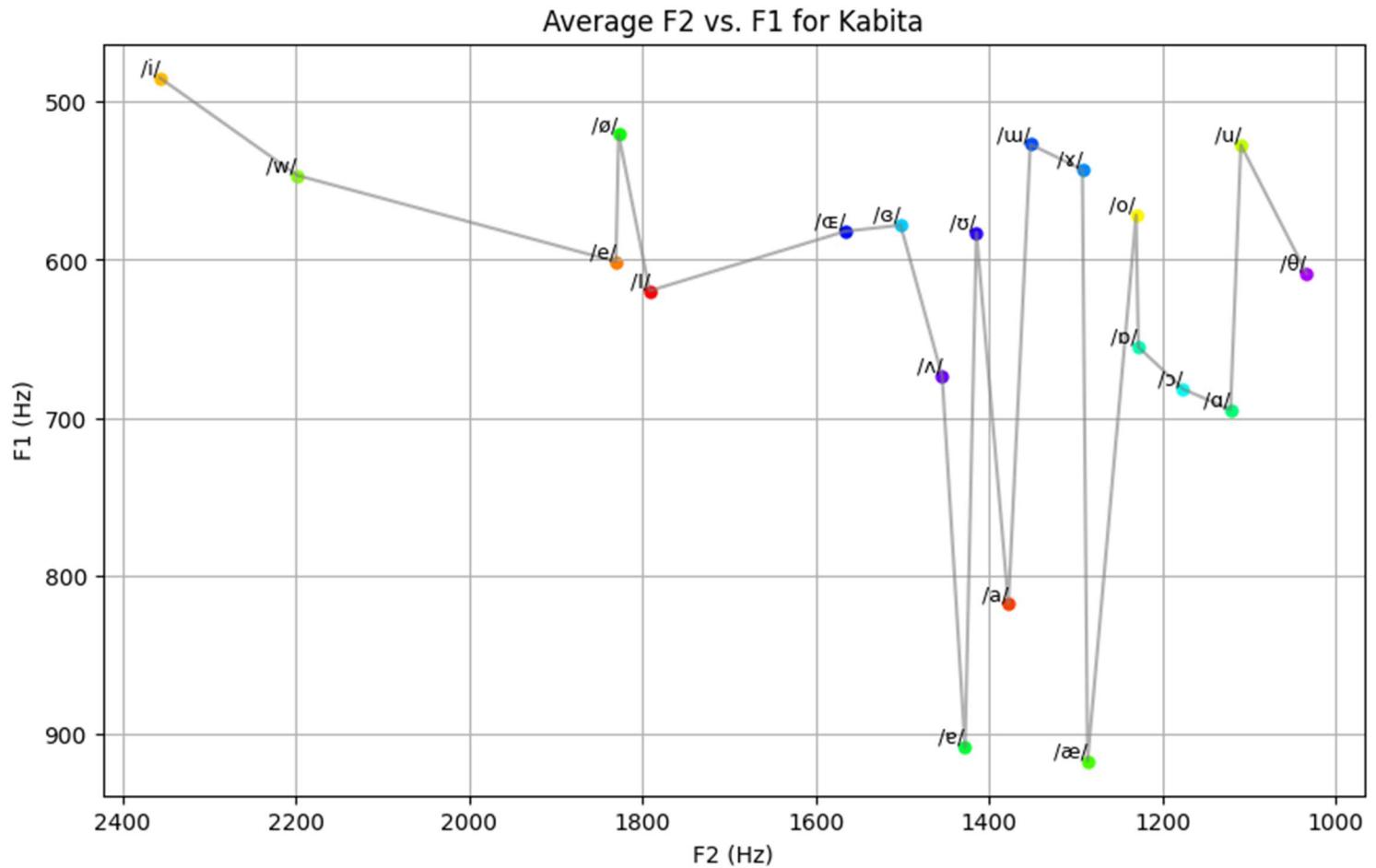
- **Front** vowels (e.g., /i/, /e/) tend to have higher F2 values and are located on the **right** side.
- **Back** vowels (e.g., /u/, /o/) have lower F2 values and are clustered on the **left** side.
- **Open** vowels (e.g., /a/) have higher F1 values and appear toward the **upper** part of the graph.
- **Close** vowels (e.g., /i/, /u/) have lower F1 values and are closer to the **bottom**.

## Kabita Boro:



Distribution Range:

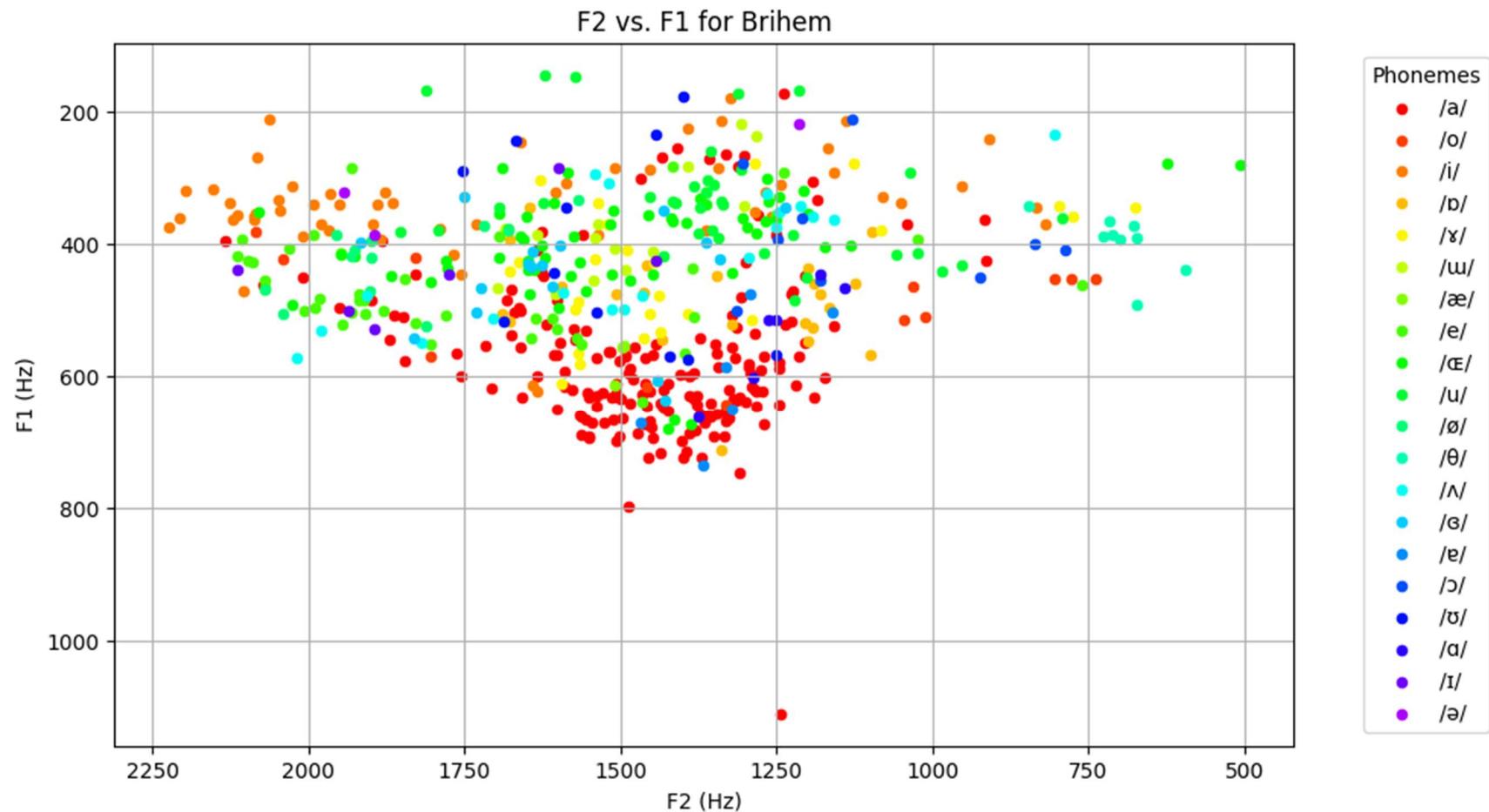
- The **F1** values range from about **300 Hz to 2000 Hz**, indicating a mix of open and close vowels.
- The **F2** values range from **500 Hz to 3000 Hz**, covering both back and front vowels.



The vowels show distinct clusters, reflecting their phonetic properties:

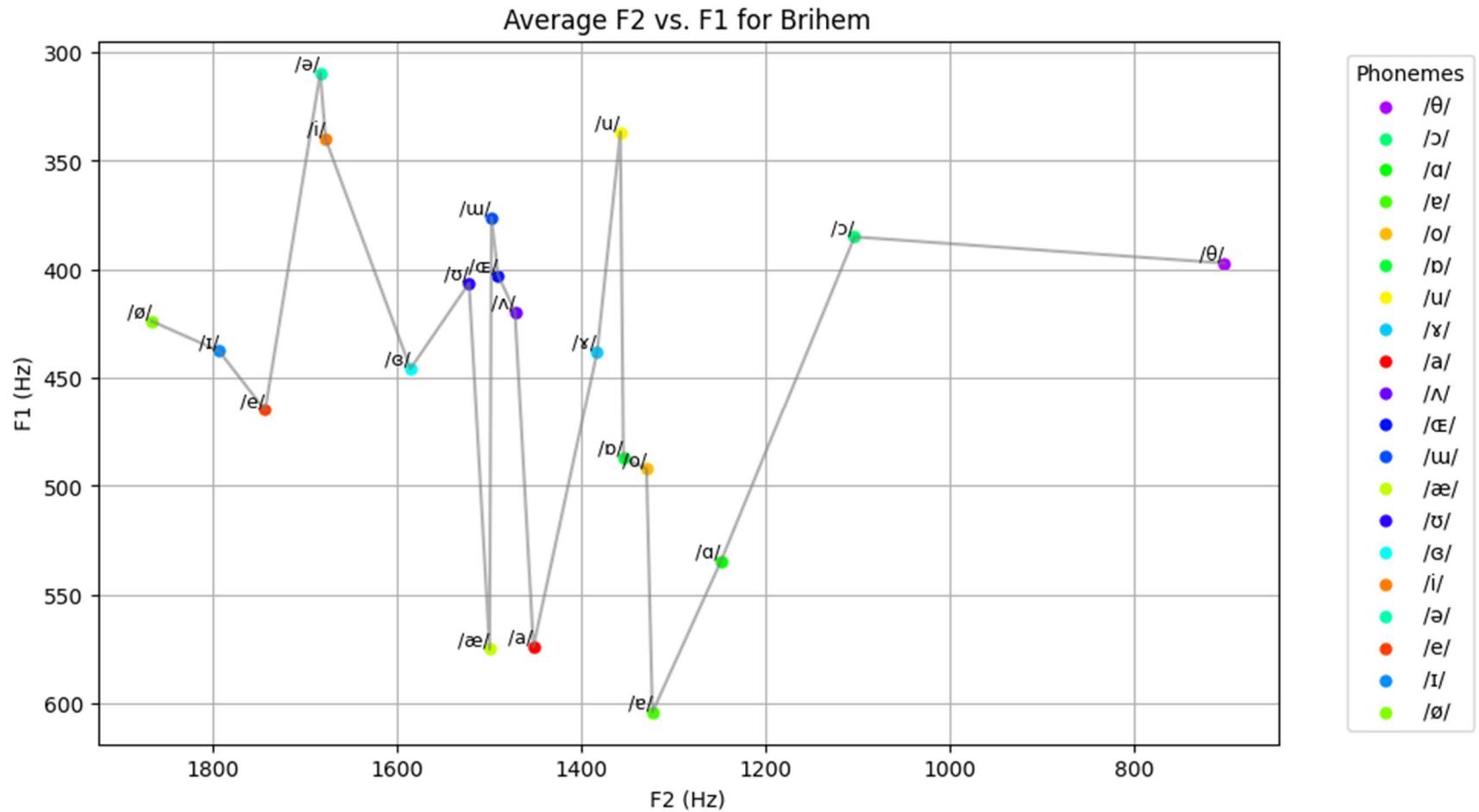
- **Front** vowels (e.g., /i/, /e/) tend to have higher F2 values and are located on the **right** side.
- **Back** vowels (e.g., /u/, /o/) have lower F2 values and are clustered on the **left** side.
- **Open** vowels (e.g., /a/) have higher F1 values and appear toward the **upper** part of the graph.
- **Close** vowels (e.g., /i/, /u/) have lower F1 values and are closer to the **bottom**.

## Brihem Basumatary:



Distribution Range:

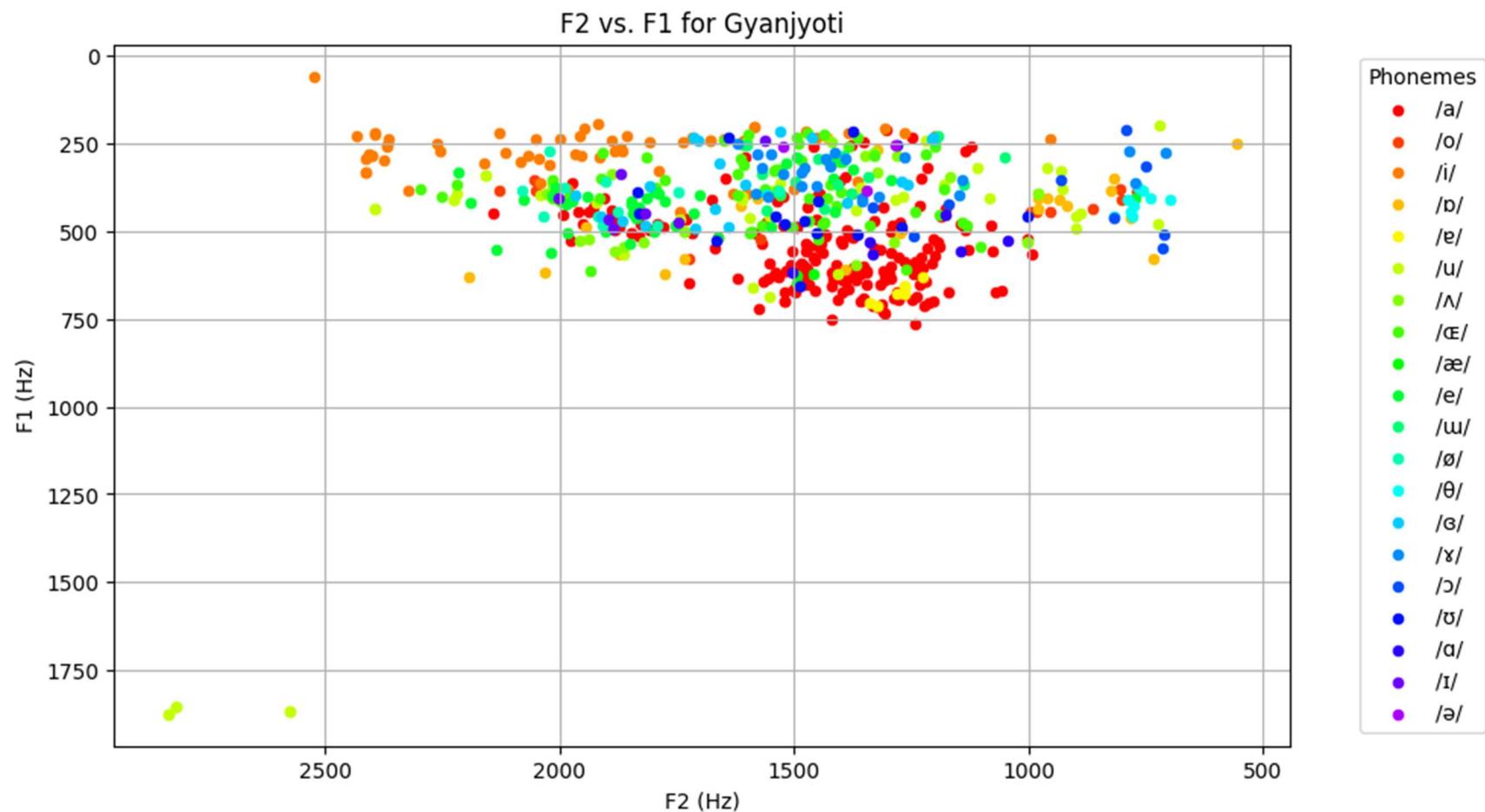
- The **F1** values range from about **150 Hz to 1000 Hz**, indicating a mix of open and close vowels.
- The **F2** values range from **500 Hz to 2250 Hz**, covering both back and front vowels.



The vowels show distinct clusters, reflecting their phonetic properties:

- **Front** vowels (e.g., /i/, /e/) tend to have higher F2 values and are located on the **right** side.
  - **Back** vowels (e.g., /u/, /o/) have lower F2 values and are clustered on the **left** side.
  - **Open** vowels (e.g., /a/) have higher F1 values and appear toward the **upper** part of the graph.
  - **Close** vowels (e.g., /i/, /u/) have lower F1 values and are closer to the **bottom**.

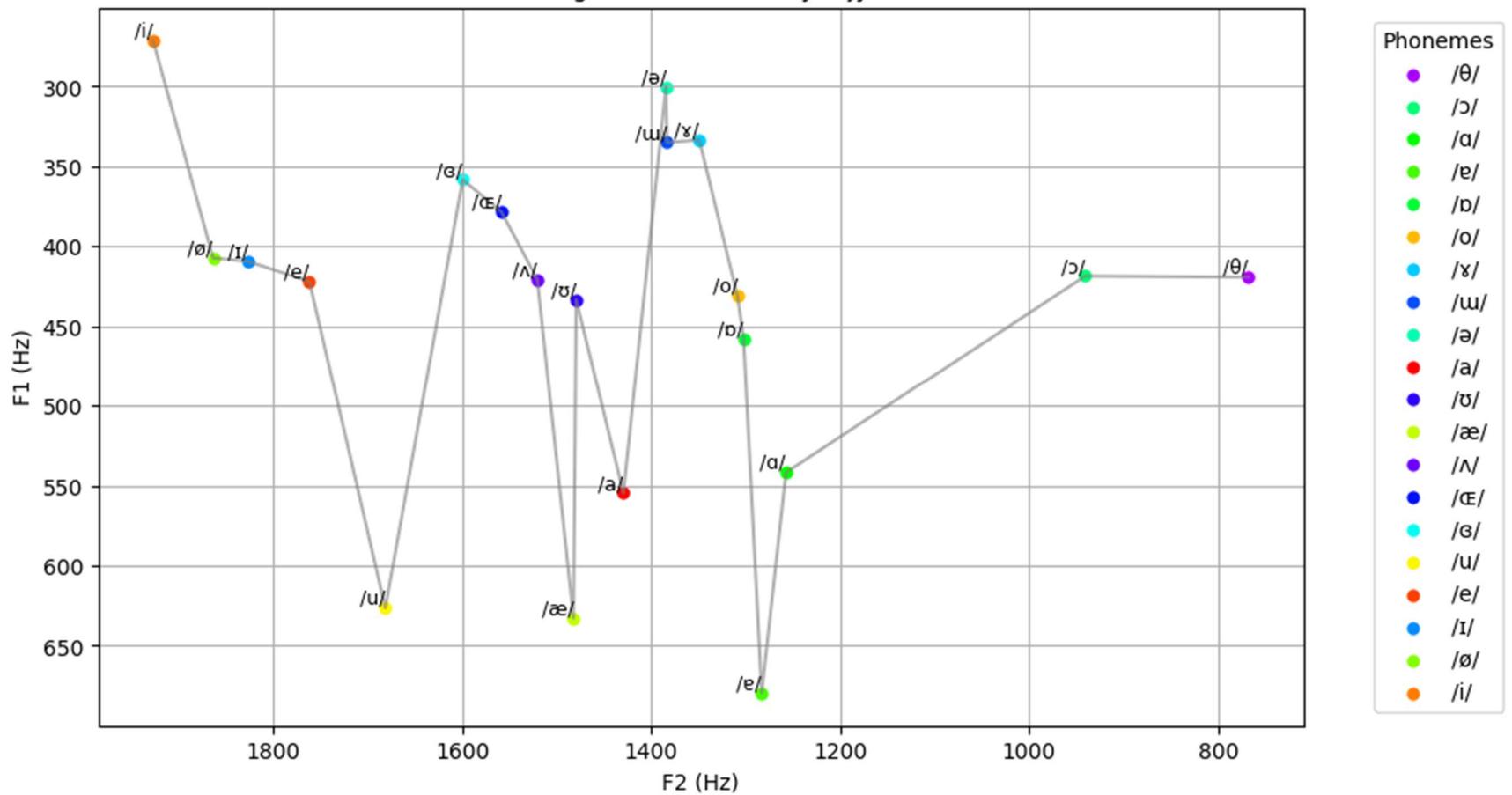
## Gyanjyoti Brahma:



Distribution Range:

- The **F1** values range from about **200 Hz to 1750 Hz**, indicating a mix of open and close vowels.
- The **F2** values range from **500 Hz to 2500 Hz**, covering both back and front vowels.

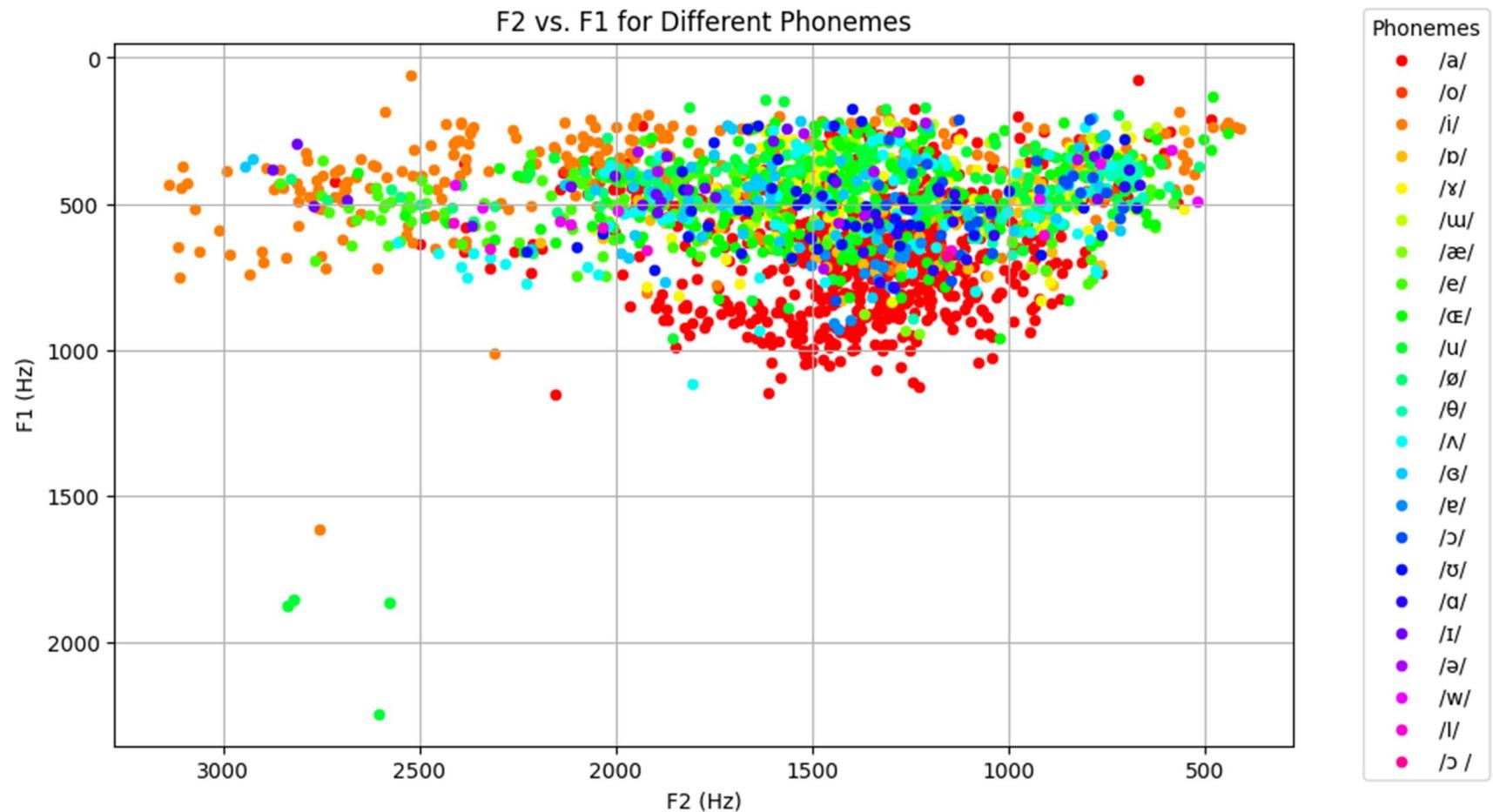
Average F2 vs. F1 for Gyanjyoti



The vowels show distinct clusters, reflecting their phonetic properties:

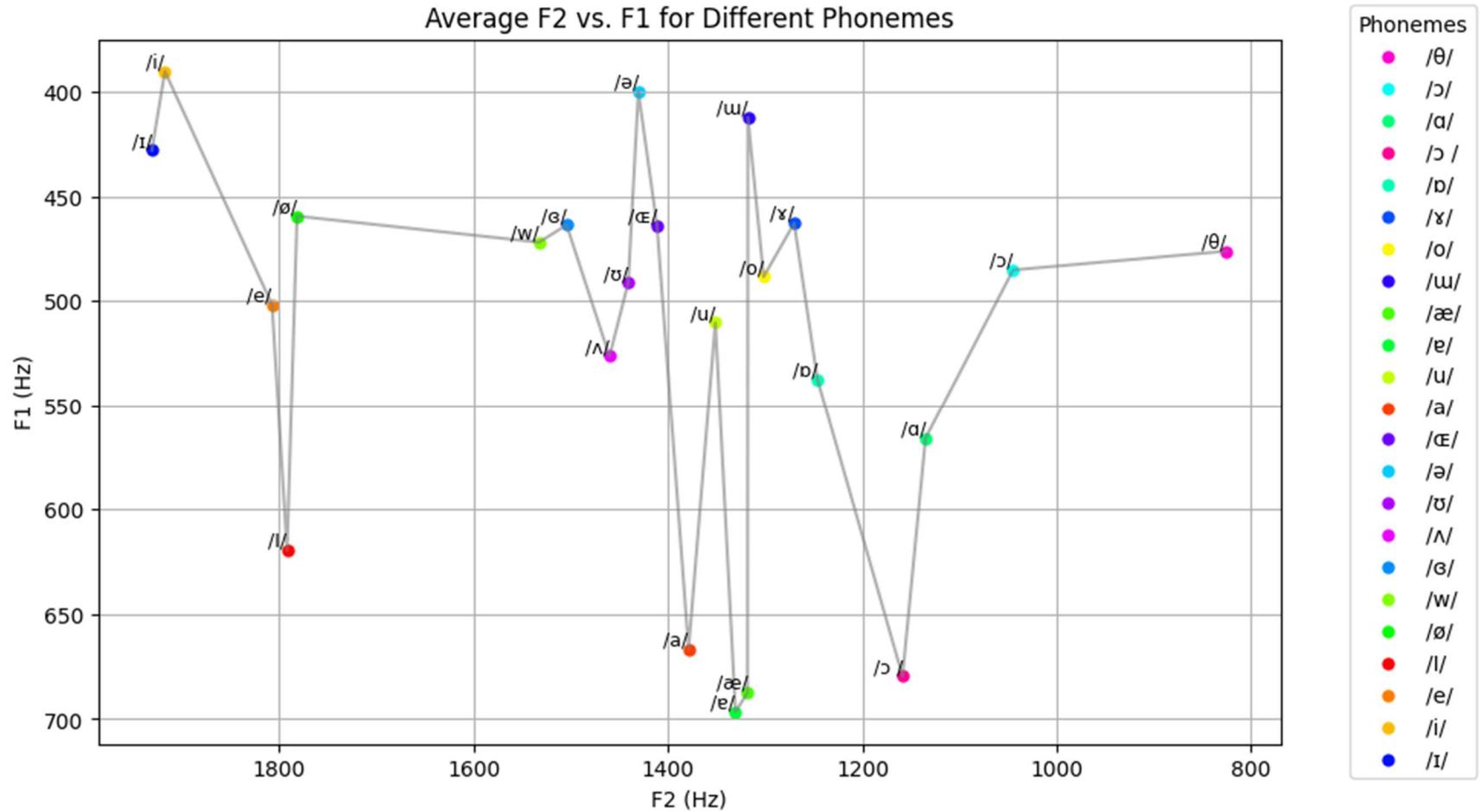
- **Front** vowels (e.g., /i/, /e/) tend to have higher F2 values and are located on the **right** side.
- **Back** vowels (e.g., /u/, /o/) have lower F2 values and are clustered on the **left** side.
- **Open** vowels (e.g., /a/) have higher F1 values and appear toward the **upper** part of the graph.
- **Close** vowels (e.g., /i/, /u/) have lower F1 values and are closer to the **bottom**.

## All Participants:



Distribution Range:

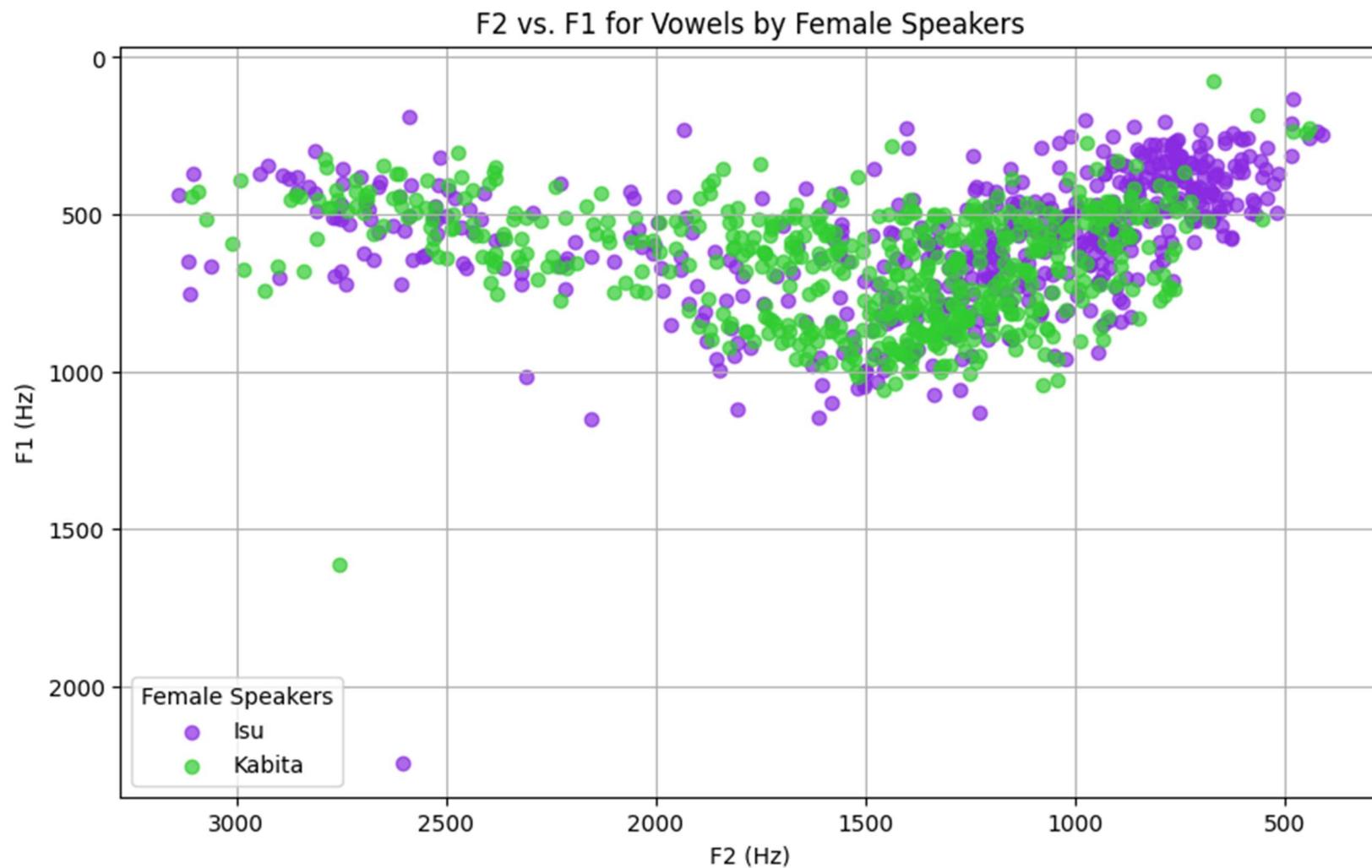
- The **F1** values range from about **150 Hz to 2000 Hz**, indicating a mix of open and close vowels.
- The **F2** values range from **500 Hz to 3000 Hz**, covering both back and front vowels.



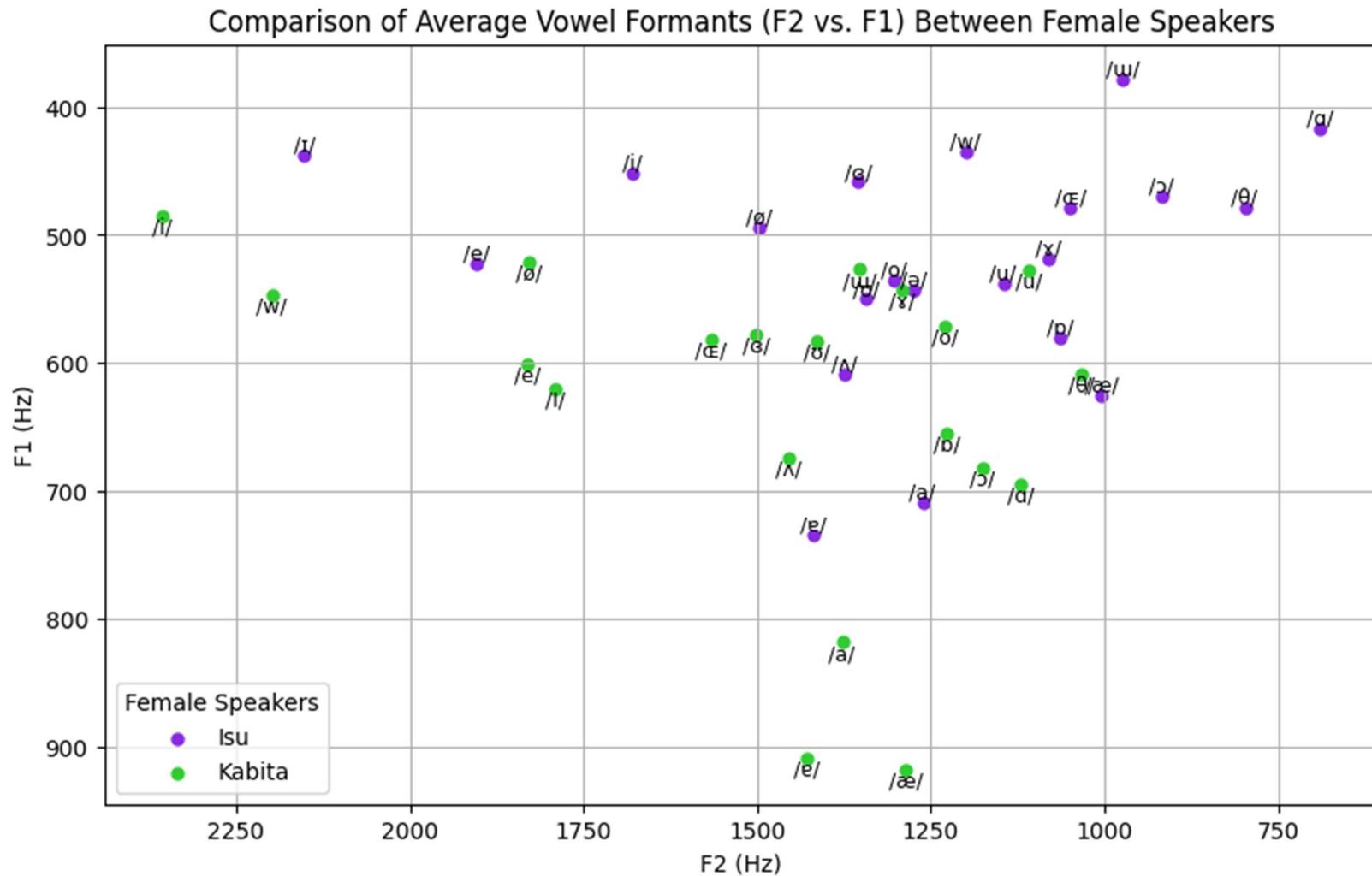
The vowels show distinct clusters, reflecting their phonetic properties:

- **Front** vowels (e.g., /i/, /e/) tend to have higher F2 values and are located on the **right** side.
  - **Back** vowels (e.g., /u/, /o/) have lower F2 values and are clustered on the **left** side.
  - **Open** vowels (e.g., /a/) have higher F1 values and appear toward the **upper** part of the graph.
  - **Close** vowels (e.g., /i/, /u/) have lower F1 values and are closer to the **bottom**.

## ***Contrast between the female participants:***

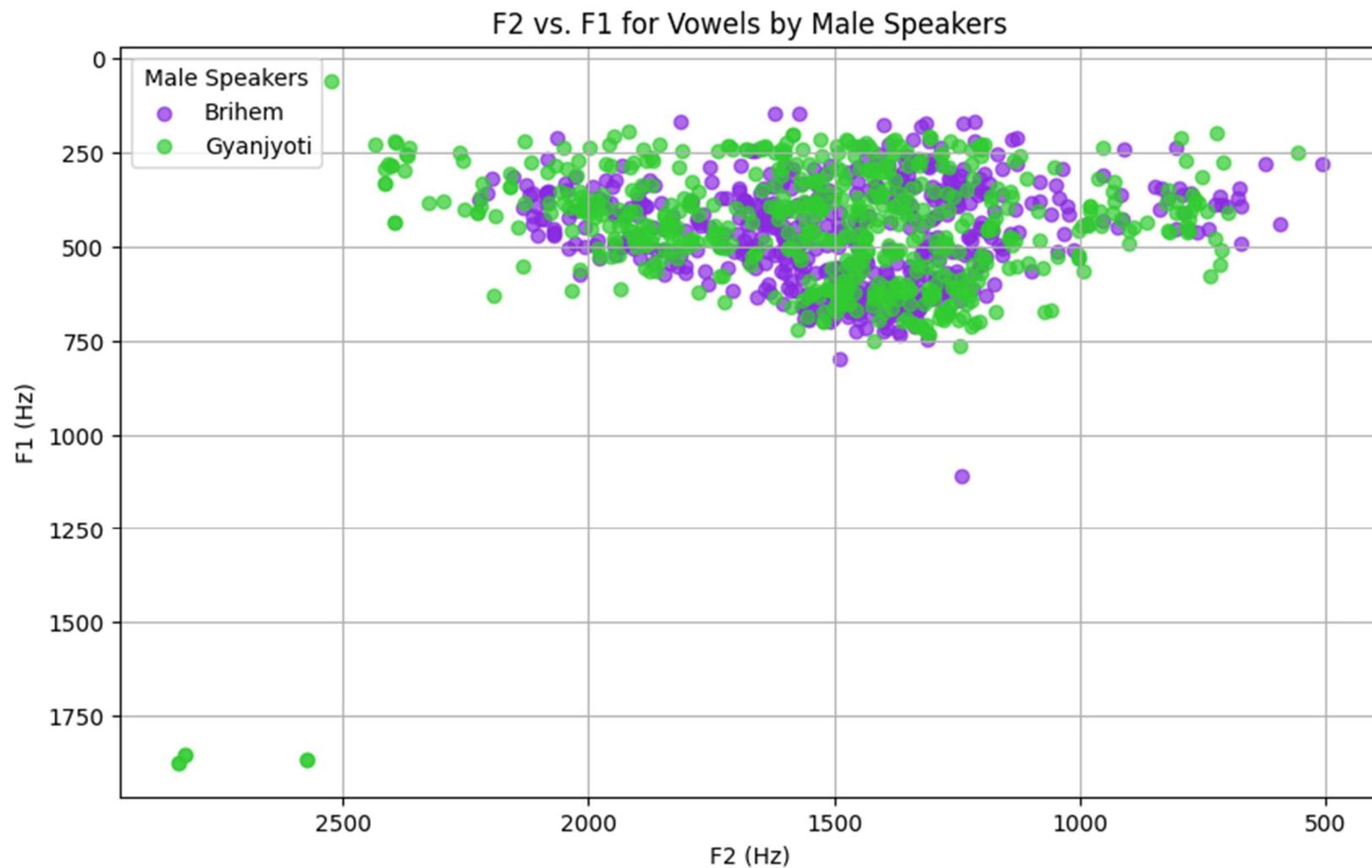


- The  $F2$  values range from **500 Hz to 3000 Hz**, covering both back and front vowels.



- For many vowels, Isu and Kabita exhibit noticeable differences in F1 and/or F2 values.
- These differences might be indicative of individual articulatory habits or subtle dialectal variations.

## ***Contrast between the male participants:***

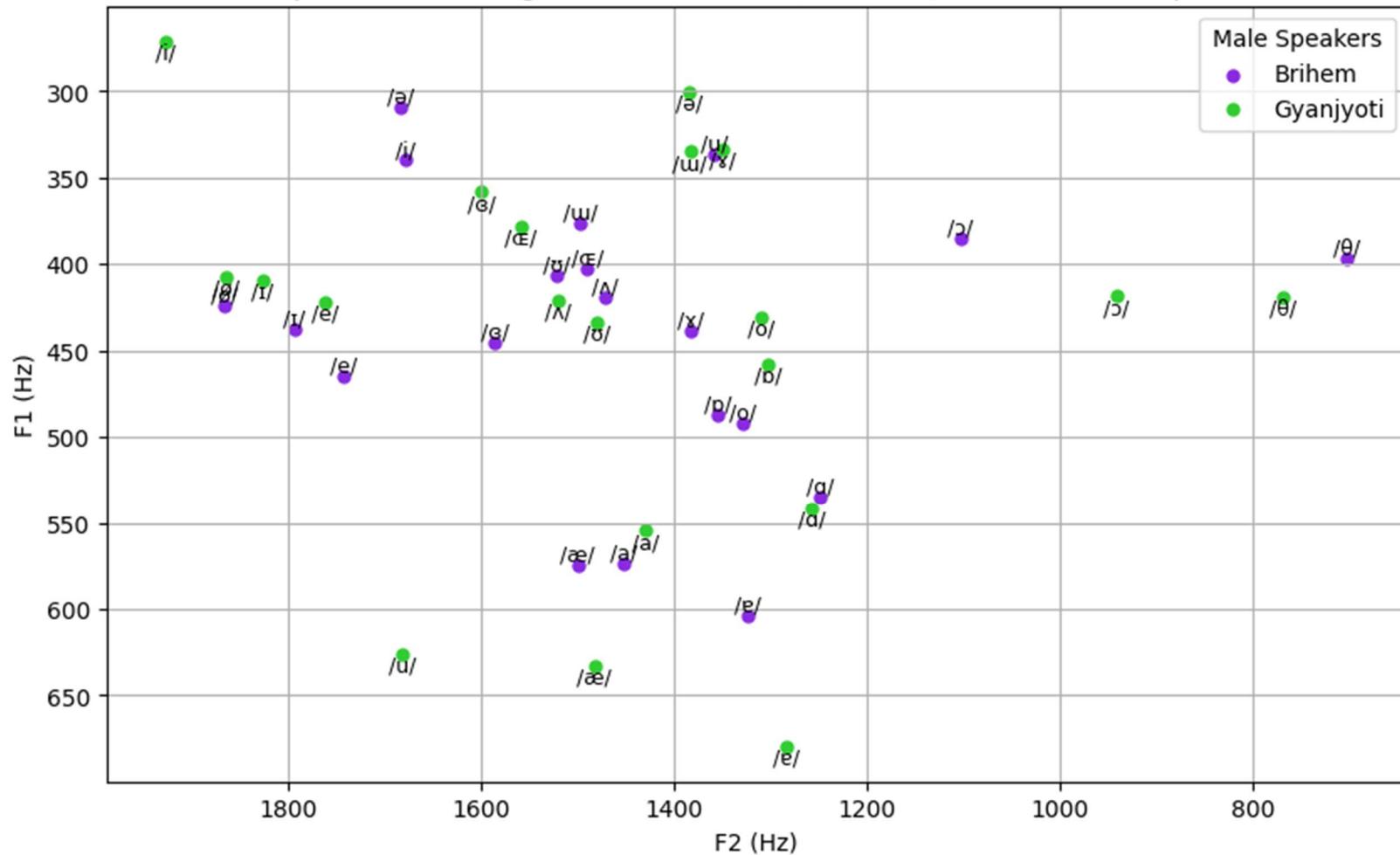


Distribution Range:

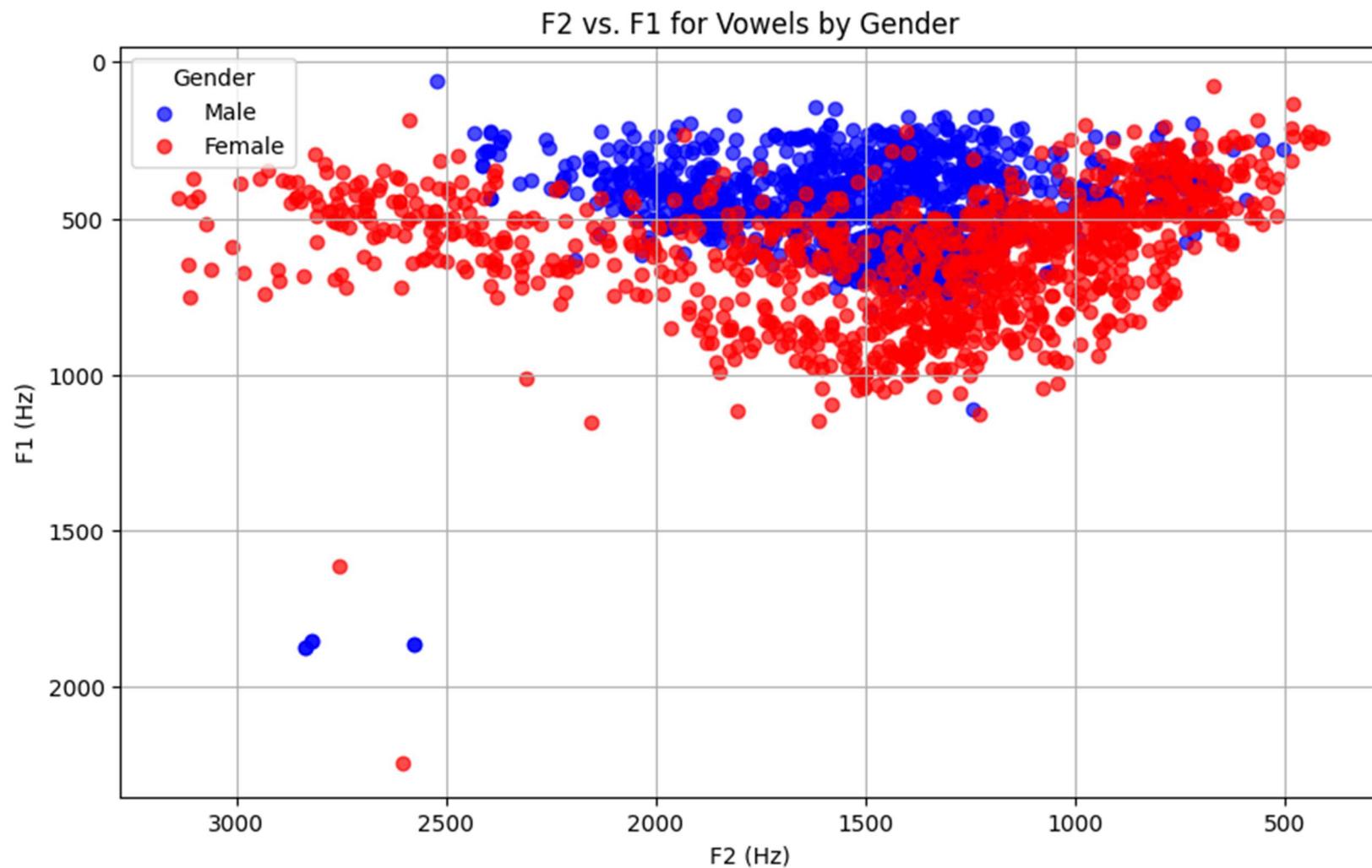
- The **F1** values range from about **150 Hz to 1750 Hz**, indicating a mix of open and close vowels.

- The  $F2$  values range from **500 Hz to 2500 Hz**, covering both back and front vowels.

Comparison of Average Vowel Formants (F2 vs. F1) Between Male Speakers

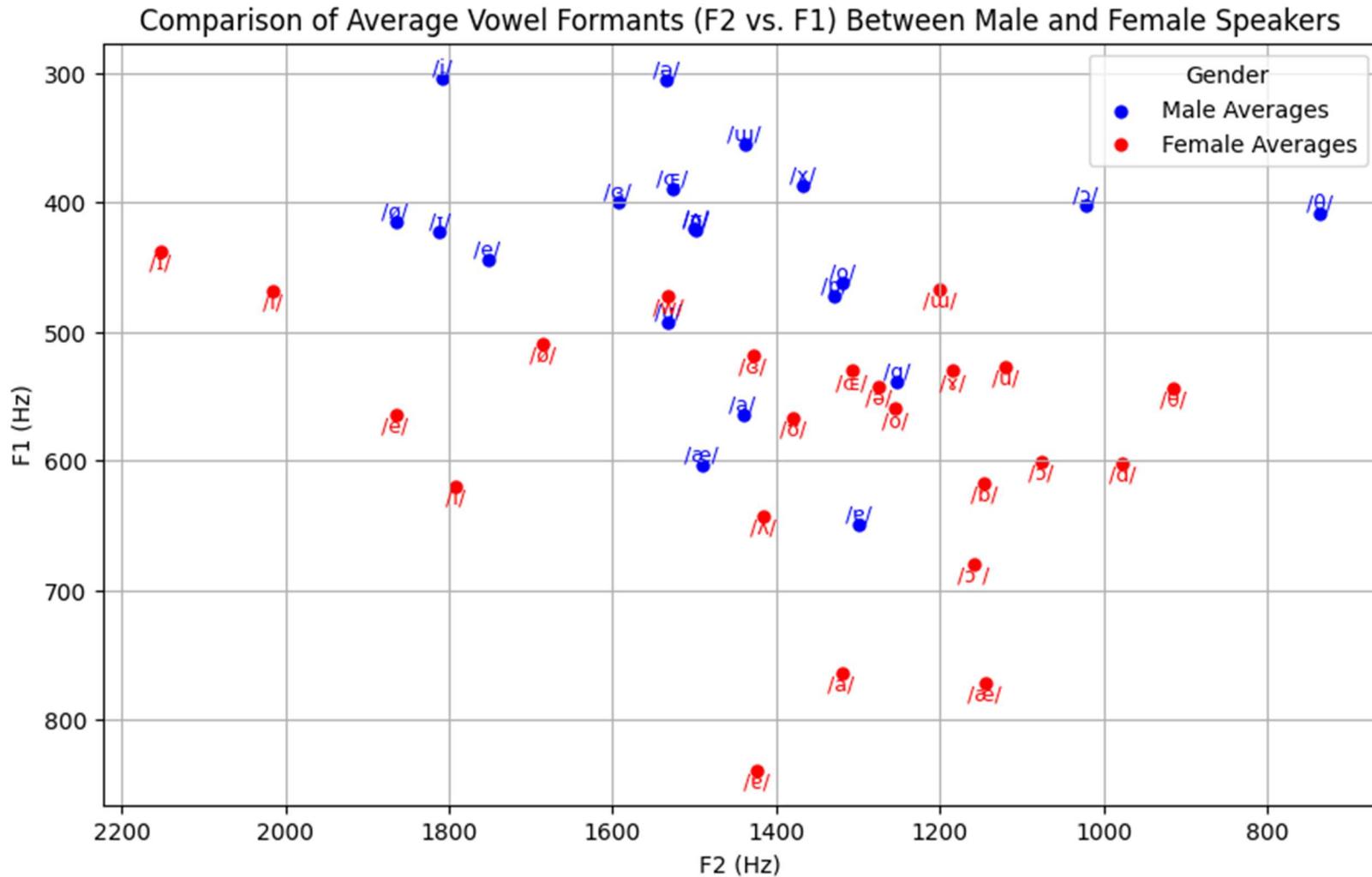


***Contrast between the male and female participants:***



Distribution Range:

- The **F1** values range from about **150 Hz to 2000 Hz**, indicating a mix of open and closed vowels.
- The **F2** values range from **200 Hz to 3000 Hz**, covering both back and front vowels.



- For many vowels, the males and females exhibit noticeable differences in F1 and/or F2 values.
- These differences might be indicative of individual articulatory habits or subtle dialectal variations.

A brief summary of the graphs:

<i>Graph Type</i>	<i>Details</i>
<b>Individual vowels per speaker</b>	Shows speaker-specific articulation differences.
<b>Average vowels per speaker</b>	Reveals trends within individual speakers.
<b>Female vowel comparison</b>	Highlights inter-speaker differences among females.
<b>Female average vowel comparison</b>	Highlights averaged trends among female speakers.
<b>Male vowel comparison</b>	Highlights inter-speaker differences among males.
<b>Male average vowel comparison</b>	Highlights averaged trends among male speakers.
<b>Gender vowel comparison</b>	Contrasts male and female vowel articulation.
<b>Gender average vowel comparison</b>	Shows gender-based averaged trends.
<b>Combined individual vowels</b>	Plots for all speakers' vowels collectively.
<b>Combined average vowels</b>	Highlights overall trends in vowel articulation.

## ***Observations***

- **Vowel Articulation Trends:** Distinct patterns in vowel articulation for the Bodo language were confirmed.
- **Gender Differences:** Female speakers exhibited higher formant frequencies.
- **Inter-Speaker Variability:** Subtle differences were observed between speakers of the same gender, likely due to individual vocal tract differences.
- **Total vowels** found in Boro language through this project in 22.

## ***Linguistic Insights***

Understanding of Bodo phonetics for potential applications in linguistic research and speech technology could be a working field of this analysis.