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MATHEMATICS MODEL IN VITALITY ANALYSIS OF THE LIMOLA LANGUAGE

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ABSTRACT

One of the regional languages in Tana Luwu, especially in North Luwu Regency, is the Limola language. Limola language is a regional language used in communication by the people of Sassa Village. This research utilizes the Pinasco and Romanelli (PR) model to analyze the vitality of the Limola language. The language's sustainability is assessed through a questionnaire with vitality indicators based on UNESCO. Meanwhile, birth and death rates are derived from statistical data from North Luwu. This research found that the model used can explain the possibility of using the Limola language by taking into the carrying capacity and average birth and death rates of users of the Limola language. There are three conditions found. The third condition, despite the birth and death rates of Limola language users being higher than those of people using other languages, the usage of the Limola language still decreases. This is because the language used to communicate as a child as an indicator of the carrying capacity of the Limola language, is very small. In addition, five out of the nine vitality indicators formulated by UNESCO are endangered, posing a threat to the survival of the Limola language.

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1. INTRODUCTION

Indonesia ranks 6th in the world as an archipelagic country, with 17,504 islands. [1] Of these, about 6,000 islands are inhabited by varied plain structures stretching from Sabang to Merauke. This condition causes a variety of cultures and languages that grow according to the situation of the natural environment. In general, the languages used in Indonesia are categorized into 3, namely Indonesian as the national language, regional languages, and foreign languages [2].

The results of research on language mapping in Indonesia were carried out in 2019. The research was carried out by the Language and Book Development Agency, Ministry of Education, and Culture, where 718 languages were identified and validated from 2,560 observation areas. This number does not include dialects and sub-dialects in Indonesia. In Tana Luwu, in particular, there are 9 regional languages and 12 tribal children. The languages are Rampi Language, Tae' Language, Bastem Language, Pamona Language, Rongkong Language, Seko Language, Limola Language, Padoe Language, and Wotu Language [3].

Analysis of the level of extinction of regional languages is important to do. Regional languages are essential of ethnic identity, and an ethnic group's survival is always linked to a particular language [4]. The extinction of language is one indication of the extinction of human civilization. Many factors have contributed to the extinction of regional languages, including speakers thinking of themselves as socially inferior, attachment to the past, traditional side, economically stagnant life, urbanization, and inter-ethnic marriages, and the most important main factor caused by parents who no longer teach and actively use the mother tongue to their children in various areas of communication [5]. Additional factors are the patterns of immigration and emigration into and out of the territory [6]. Furthermore, Fanny H. Tondo divides the factors of extinction of regional languages into two major parts, namely natural factors and non-natural factors. Natural factors are natural disasters, the influence of the majority language, the existence of bilingual or even multilingual language communities, globalization, migration, and inter-ethnic marriages. Meanwhile, non-natural factors can be in the form of a lack of appreciation for the existence of regional languages, the lack of intensity in using regional languages in daily life, economic factors, and the use of Indonesian [7].

One of the regional languages in Tana Luwu, especially in North Luwu Regency, is the Limola language. Limola language is a regional language used in communication by the people of Sassa Village. The Limola language is hereditary and comes from the Tomanurung language. The use of regional languages has begun to be eroded or shifted by the more dominant language used by the wider community. This also occurs in the use of the Limola language in the community in Sassa Village, North Luwu Regency, as the area where the regional language is located. In everyday conversation, the Limola language is no longer dominantly used in communication, even within the family circle. Benu, et al. [8] fund that regional language is evolving, especially in how it is used in public places. Several other studies have also found the same thing such as Mulyawan, et al. [9] and Savski [10] showed that the number of regional language uses in public spaces is decreasing.

Several studies have been carried out by several researchers related to the regional languages in Tana Luwu. However, this study has not examined specifically related to each existing language. The research conducted is more dominant in the Tae' and Wotu languages. The existing research only examines the morphosyntactic of the Tae's language [11], pragmatic analysis [12], an ethnographic analysis that discusses the message and function of the Tae's language expressions [13], *as well as* Prepositions and Conjunctions in the Tae' Language [14]. In addition, there are also studies related to the Wotu language, such as “Wotu Language In Endangered Phase: Solution For Revitalizing Wotu Language: conducted by Masruddin in 2015 [15], and “The Use of Wotu, Bugis and Indonesian Languages in Four Language Areas in Lampenai Village and Bawalipu Village (Sociolinguistic Studies)” conducted by Muh. Nur Assyddyq in 2016 [16].

From the technique used, Winci Firdaus analyzed the level of vitality of the Suwawa language using sociolinguistic theory and Fishman's theory of vitality and the criteria for language vitality using Grimes' criteria [17]. The same thing was also done by Santy Yulianti and Winci Firdaus, who analyzed the vitality of the Roswar language in Waprak and Nordiwar villages, Roswar District, Teluk Wondama Regency, West Papua Province [18].

Tissa Putri Yunita and Mahdhivan Syafwan try to make a mathematical model of competition between Gaelic languages in Ross and Cromarty Scotland, for monolingual communities and Malay in Brunei for bilingual communities [19]. The competition model is derived by first looking at the system of two competing languages as X and Y, with the total proportion of speakers of the two languages being 1. Nadiatur Rahma et

al. did a different thing, they derived the mathematical model of Minang and Indonesian in the form of a differential equation and then looked at its dynamics around the equilibrium point [20].

Different from what has been done by previous research, the mathematical model that will be derived in this study includes birth rates, migration, inter-ethnic marriages, and the existence of a bilingual or multilingual language community, which Fanny H. Tondo calls some of the factors that influence the extinction of language regions in Indonesia [7]. In addition, research on the phenomenon of the Limola language shift has also never been carried out. This research employs the Pinasco and Romanelli model (PR model), which adopts the Lotka-Volterra model (Equations (1.a) and (1.b)) as proposed by Patriarca [21]. However, in this study, all equilibrium points that occur are identified and adjusted to the context of the Limola language phenomenon, whereas Patriarca only indicates a single equilibrium point.

2. RESEARCH METHODS

The type of research is field research with a descriptive quantitative approach. The research subjects are residents who live and settle in Sassa Village, Baebunta District, North Luwu Regency. The subjects to be taken are from 2 hamlets of native speakers of the Limola language, totalling 149 people.

The instruments in this research are questionnaires and interview sheets. Questionnaires were used to obtain data on the use of the Limola language. The questionnaire is arranged based on the pattern of language used by speakers. The questionnaire focuses more on the use of language in the realm of family and neighbourhood. The choice of domains is because these two domains are the closest to the use of regional languages. The family domain is the smallest community group that can describe the actual portrait of community groups in the use of language. The interview instrument was constructed using the vitality indicators suggested by UNESCO, encompassing the nine key factors for evaluating language vitality. These factors include intergenerational language transmission, number of speakers, proportion of speakers to the total population, language use trends, responsiveness to media, language education materials, government language policies, the community's attitude toward its own language, as well as the quantity and quality of language documentation.[22] In addition, interview instruments were also used to obtain data related to the mathematical modelling of the Limola language.

The data obtained from questionnaires and interviews are further processed in the following:

1. The data from the questionnaires are first tabulated and assigned codes. If there are respondents who did not provide answers to one or more statements/questions in the questionnaire, that questionnaire cannot be taken as a data source.
2. The interview data in this study are divided into two categories: interview data related to vitality indicators based on UNESCO and interview data related to the quantity of each variable used to construct the Limola language mathematical model. Interview data related to vitality indicators are obtained by asking each of the 9 vitality indicators to the respondents one by one. This interview technique is used to ensure that the information obtained truly reflects the actual situation. Additionally, it is used to obtain information related to factors that directly influence the shift in the use of the Limola language. The interview data are then tabulated, reduced, evaluated, and interpreted.
3. The mathematical model used for the case of Limola language vitality is the model developed by Pinasco and Romanelli, later referred to as the Pinasco Romanelli (PR) model. The data from the questionnaires and interviews are used to determine the parameter values in this PR model. Additionally, some assumptions are made for possible scenarios.

3. RESULTS AND DISCUSSION

The Pinasco and Romanelli model, commonly referred to as the PR model, is a population dynamics model introduced by Pinasco and Romanelli in 2006. This model adopts the Lotka-Volterra model. The PR model in equation is as follows [21]:

$$\frac{dx(t)}{dt} = cxy + \alpha_x x\left(1 - \frac{x}{K_x}\right) \quad (1.a)$$

$$\frac{dy(t)}{dt} = -cxy + \alpha_y y\left(1 - \frac{y}{K_y}\right) \quad (1.b)$$

The population $x(t)$ and $y(t)$ are the number of people using language x and y in a certain period. y is a less attractive language to use, in this case the Limola language. c is the rate of switching from language y to language x. Speed is a scalar quantity; it has no direction but only a value, so the speed is always positive. For $c > 0$, the model can be used to measure the rate of switching of users of language y to language x, K_x, and K_y are a carrying capacity, α_x and α_y are the average birth and death rates.

Speakers of languages x and y can survive at the same time in a balanced and stable state when the number of minority language users y can grow rapidly, in this case, the growth rate is faster than the rate at which members turn into individuals who use language x. This condition can be met if

$$cK_x < \alpha_y \quad (2)$$

First, the equilibrium point will be determined from **Equation (1)**. The equilibrium point of **Equation (1.a)** and **Equation (1.b)** is the value (x, y) that satisfies the following conditions:

$$0 = cxy + \alpha_x x\left(1 - \frac{x}{K_x}\right) \quad (3)$$

$$0 = -cxy + \alpha_y y\left(1 - \frac{y}{K_y}\right) \quad (4)$$

For $x = 0$, it is clear that the value of y = 0 is obtained. So, the first equilibrium point is $e_1 = (0,0)$. Furthermore, for $x = 0$ also obtained $y = K_y$ so that **Equation (3)** and **Equation (4)** are fulfilled. From here obtained the second equilibrium point is $e_2 = (0, K_y)$. Likewise for $y = 0$ obtained $x = K_x$ so that **Equation (3)** and **Equation (4)** are fulfilled. So, the third equilibrium point is $e_3 = (K_x, 0)$. It's easy to show that $x = \frac{K_x\alpha_y(cK_y+\alpha_x)}{K_xK_yc^2+\alpha_x\alpha_y}$ and $y = \frac{K_y\alpha_x(\alpha_y-cK_x)}{K_xK_yc^2+\alpha_x\alpha_y}$. So the fourth equilibrium point is $e_4 = \left(\frac{K_x\alpha_y(cK_y+\alpha_x)}{K_xK_yc^2+\alpha_x\alpha_y}, \frac{K_y\alpha_x(\alpha_y-cK_x)}{K_xK_yc^2+\alpha_x\alpha_y}\right)$.

The equilibrium point $e_1 = (0,0)$ means that there are no more local people who use language x and language y, in this case, the users of language x and users of language y are both equal to 0. This is not possible. So, the behavior of the system around the equilibrium point $e_1 = (0,0)$ will not be noticed. The equilibrium point $e_2 = (0, K_y)$ means that there are no more users of language x, the same thing for the equilibrium point $e_3 = (K_x, 0)$ which also means that there are no more users of language y. This can happen but, in this case, the number of users of each language x and language y is still there even though the number is different. So, the behavior of the system around the equilibrium points e_2 and e_3 in this case, will not be noticed. The fourth equilibrium point $e_4 = \left(\frac{K_x\alpha_y(cK_y+\alpha_x)}{K_xK_yc^2+\alpha_x\alpha_y}, \frac{K_y\alpha_x(\alpha_y-cK_x)}{K_xK_yc^2+\alpha_x\alpha_y}\right)$ is the one that best fits the current situation of the Limola language, where in quantity the number of users is less than the number of other language users such as Luwunese and Indonesian in Sassa Village. So, from the four existing equilibrium points, in this case, only the behavior of the system will be seen around the equilibrium point e_4.

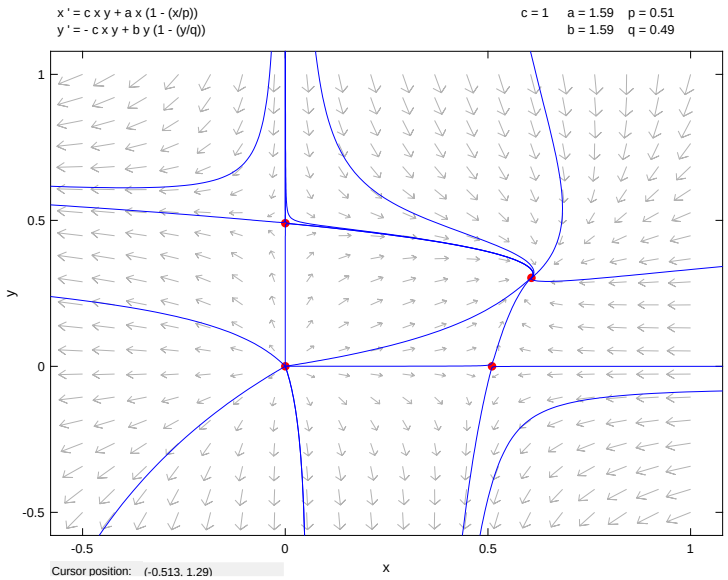


Figure 1. System Behavior with Four Equilibrium

Furthermore, the stability of the system in the case of the Limola language vitality can be determined by observing the behavior of the system around the equilibrium point $e_4 = \left(\frac{K_x\alpha_y(cK_y+\alpha_x)}{K_xK_yc^2+\alpha_x\alpha_y}, \frac{K_y\alpha_x(\alpha_y-cK_x)}{K_xK_yc^2+\alpha_x\alpha_y}\right)$. Note that the PR system of equations is a nonlinear system of equations, so mathematically, it will first be linearized around the equilibrium point e_4 by solving the Jacobian matrix. See **Equation (5)**.

$$J = \begin{bmatrix} c\left(\frac{K_y\alpha_x(\alpha_y-cK_x)}{K_xK_yc^2+\alpha_x\alpha_y}\right)+\alpha_x & c\left(\frac{K_x\alpha_y(cK_y+\alpha_x)}{K_xK_yc^2+\alpha_x\alpha_y}\right) \\ -2\frac{\alpha_x}{K_x}\left(\frac{K_x\alpha_y(cK_y+\alpha_x)}{K_xK_yc^2+\alpha_x\alpha_y}\right) & -c\left(\frac{K_x\alpha_y(cK_y+\alpha_x)}{K_xK_yc^2+\alpha_x\alpha_y}\right)+\alpha_y \\ -c\left(\frac{K_y\alpha_x(\alpha_y-cK_x)}{K_xK_yc^2+\alpha_x\alpha_y}\right) & -2\frac{\alpha_x}{K_x}\left(\frac{K_y\alpha_x(\alpha_y-cK_x)}{K_xK_yc^2+\alpha_x\alpha_y}\right) \end{bmatrix} \quad (5)$$

By solving the equation $\|\lambda I - J\| = 0$, the characteristic roots polynomial will be obtained around the equilibrium point e_4 is

$$\lambda_{1,2} = \frac{\begin{pmatrix} cA+\alpha_x \\ -2\frac{\alpha_x}{K_x}B \end{pmatrix}+\begin{pmatrix} -cB+\alpha_y \\ -2\frac{\alpha_x}{K_x}A \end{pmatrix} \pm \sqrt{\left(\begin{pmatrix} cA+\alpha_x \\ -2\frac{\alpha_x}{K_x}B \end{pmatrix}+\begin{pmatrix} -cB+\alpha_y \\ -2\frac{\alpha_x}{K_x}A \end{pmatrix}\right)^2 -4\left(\begin{pmatrix} cA+\alpha_x \\ -2\frac{\alpha_x}{K_x}B \end{pmatrix}\begin{pmatrix} -cB+\alpha_y \\ -2\frac{\alpha_x}{K_x}A \end{pmatrix}+c^2BA\right)}}{2} \quad (6)$$

The behavior of the system around the equilibrium point e_4 can be determined by analyzing every possible parameter of the real part of the eigenvalues in **Equation (6)** with the limitations and interpretations of each parameter as follows:

1. The mathematics model can be used to measure the switching rate of users of language y (the Limola Language) to language x (Other languages) for $c > 0$, where K_x and K_y are carrying capacity, α_x and α_y are the average birth and death rates.
2. The value of the parameters of the carrying capacity of K_x and K_y can be 0 which means that there is no support for each use of the Limola language and other languages. However, the value of $K_x = 0$ or $K_y = 0$ will mathematically cause **Equation (1.a)** and **Equation (1.b)** to be undefined. So, the parameter values of K_x and K_y must be both positive, in this case $K_x > 0$ and $K_y > 0$.

3. The average birth and death rates for users of each of the Limola's and other languages are α_x and α_y must be positive or in this case $\alpha_x > 0$ and $\alpha_y > 0$. This is because a certain period of birth and death rates can't be 0 or not exist at all.
4. The number of language users *x* and *y* can survive at the same time in a balanced and stable state when the number of minority language users *y* can grow rapidly, in this case, the growth rate is faster than the rate at which its members turn into individuals who use language x. This condition can be met if $cK_x < \alpha_y$.

Based on the limitations and interpretation of these parameters, the behavior of the system around the equilibrium point will be seen $e_4 = \left(\frac{K_x\alpha_y(cK_y+\alpha_x)}{K_xK_yc^2+\alpha_x\alpha_y}, \frac{K_y\alpha_x(\alpha_y-cK_x)}{K_xK_yc^2+\alpha_x\alpha_y}\right)$ by taking each parameter $c > 0, K_x > 0, K_y > 0, \alpha_x > 0, \alpha_y > 0$ serta $cK_x < \alpha_y$.

Based on the results of data analysis on the vitality questionnaire instrument given to 149 residents of Sassa Village, Baebunta, Luwu Utara, the proportion of the carrying capacity of the Limola language is 0.49 $(K_x = 0.49)$, and the proportion of the carrying capacity of other languages is 0.51$(K_y = 0.51)$. For details, see **Table 1**.

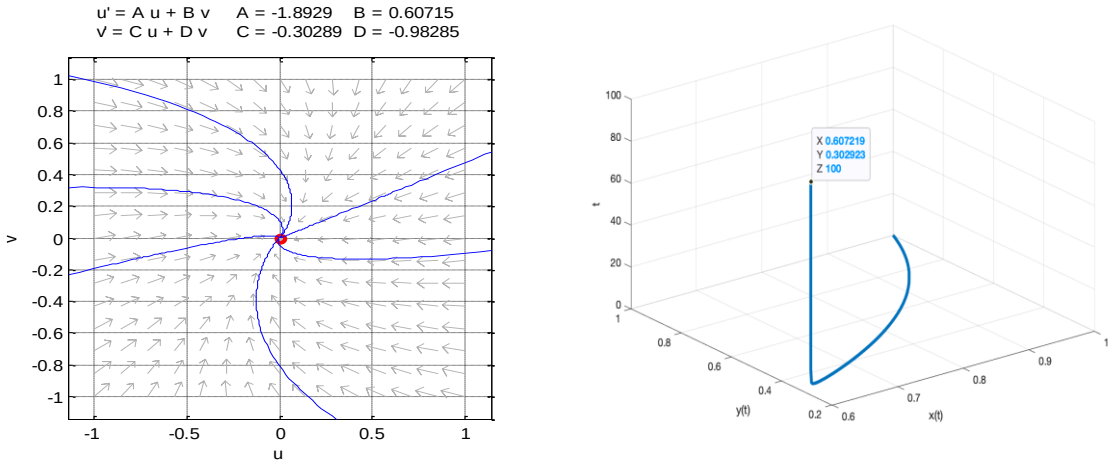
Table 1. The Proportion of The Carrying Capacity of The Language in Sassa

Name of Region /Tribe	Place of birth	Ethnic group	Where to Live Now	Main Dialect Language	Father's Language	Mother tongue	The language used to communicate as parents	The language used to communicate as a child	Language in general	Total	Proportion
Indonesian	-	0	0	24	5	2	6	9	6	52	3,878
Bone (Bugis)	2	7	0	2	8	6	1	0	1	27	2.013
Buso	1	0	0	0	0	0	0	0	0	1	0.075
Dili	2	1	0	0	0	0	0	0	0	3	0.224
Java	0	0	0	0	2	2	0	0	0	4	0.298
Kendari	1	0	0	0	0	0	0	0	0	1	0.075
Lamundre	1	0	0	0	0	0	0	0	0	1	0.075
Lanipa	1	0	0	0	0	0	0	0	0	1	0.075
Limola	**129**	**131**	**149**	**45**	**68**	**75**	**35**	**4**	**20**	**656**	**48,919**
Luwu	0	7	0	78	3	15	26	81	57	267	19.911
Malaysia	1	0	0	0	0	0	0	0	0	1	0.075
Masamba	4	0	0	0	0	0	0	0	0	4	0.298
Makassar	0	0	0	0	0	1	0	0	0	1	0.075
Palopo	1	0	0	0	0	0	0	0	0	1	0.075
Palu	1	1	0	0	0	0	0	0	0	2	0.149
Pulao	1	0	0	0	0	0	0	0	0	1	0.075
Rampi	0	1	0	0	1	1	0	0	0	3	0.224
Sabbang	3	0	0	0	0	0	0	0	0	3	0.224
Sengkang	1	0	0	0	0	0	0	0	0	1	0.075
Tolaki	0	1	0	0	1	0	0	0	0	2	0.149
Toraja	0	0	0	0	1	0	1	0	0	2	0.149
Without explanation	0	0	0	0	60	47	80	55	65	307	22.893
	149	149	149	149	149	149	149	149	149	1341	100

***Data source**: (Research Results Data for 2021)*

Meanwhile, the death and birth rates of Sassa villagers, both users of the Limola language and other languages, are taken from data on the number of births in Baebunta District in 2021, which is 1.59.

First. Value $\alpha_x = \alpha_y$ with $\alpha_x = \alpha_y > 0$. In this condition, the birth and death rates of residents who use the Limola language are the same as the birth and death rates of those who use other languages. The equilibrium points e_4 for the value $K_x = 0.510, K_y = 0490, \alpha_x = \alpha_y = 1.59, c = 1$ is $e_4 = (0.607, 0.303)$. The behavior of the PR system can be seen in **Figure 1**. The eigenvalues are real and negative, that is$(\lambda_1 = -0.941, \lambda_2 = -1.716)$ the behavior of the system around the equilibrium point is asymptotically stable with the type of equilibrium point being *sinks*. The linearization around the equilibrium point $e_4 = (0.607, 0.303)$ is shown in **Figure 2**.

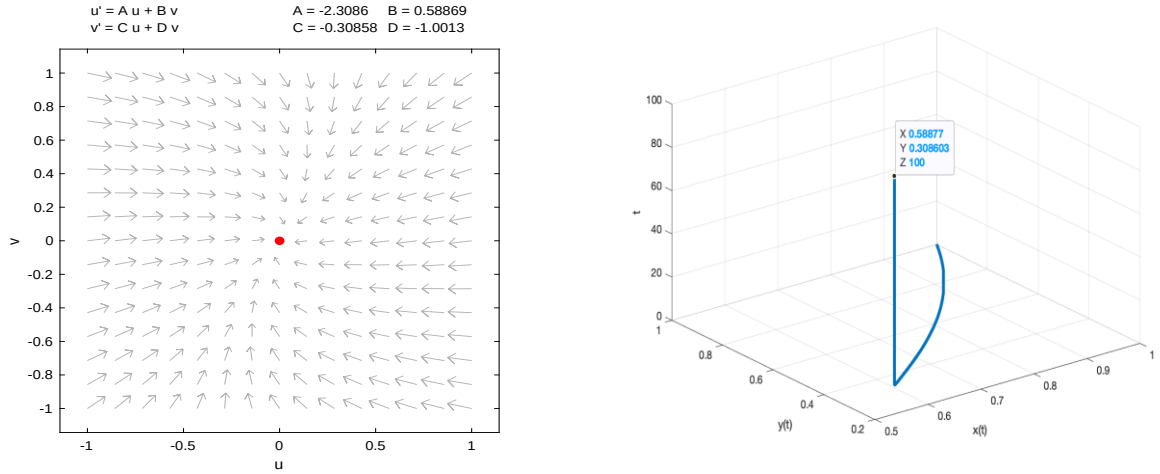


(a) **(b)**

Figure 2. $K_x = 0.510, K_y = 0490, \alpha_x = \alpha_y = 1.59, c = 1$ and Initial Condition (1, 1)
(a). Linearization Around e_4. (b). System Behavior for e_4

Based on **Figure 2**, if the birth and death rates of residents who use the Limola language are the same as the birth and death rates of those who use other languages, slowly the number of people who use the Limola language decreases faster than people who use other languages.

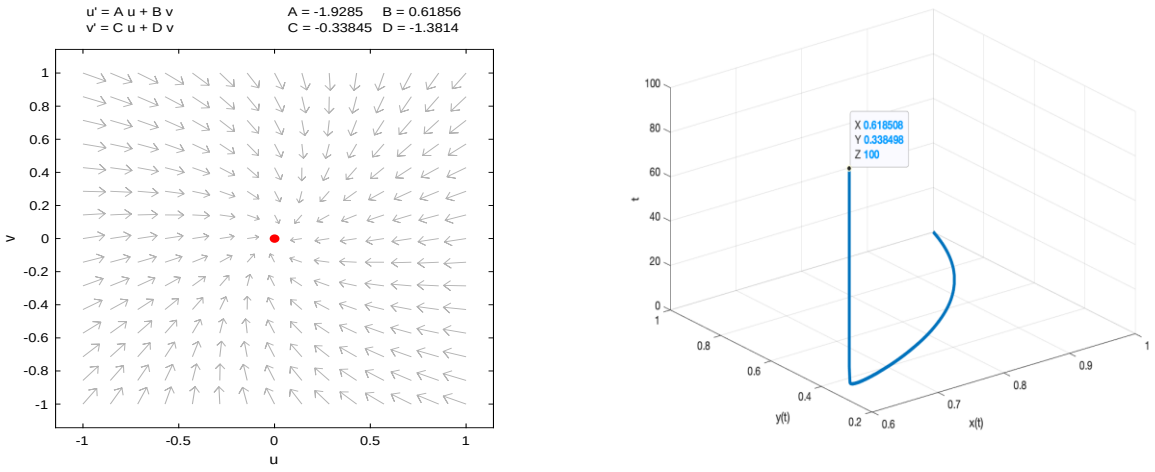
Second. Value with$\alpha_x > \alpha_y$ with $\alpha_x = \alpha_y > 0$. In this condition, the birth and death rates of residents who use the Limola language are lower than the birth and death rates of those who use other languages. The equilibrium point e_4 for the value $K_x = 0.510, K_y = 0490, \alpha_x = 2, \alpha_y = 1.59, c = 1$ is $e_4 = (0.59, 0.31)$. The behavior of the PR system can be seen in **Figure 4**. The eigenvalues are real and negative, that is $(\lambda_1 = -1{,}736, \lambda_2 = -1.991)$ the behavior of the system around the equilibrium point is asymptotically stable with the type of equilibrium point being sinks. The linearization around the equilibrium point $e_4 = (0.59, 0.31)$ is shown in **Figure 3**.



(a) **(b)**

Figure 3. $K_x = 0.510, K_y = 0490, \alpha_x = 2, \alpha_y = 1.59, c = 1$ and Initial Condition (1, 1)
(a). Linearization Around e_4. (b). System Behavior for e_4

Third. Value with $\alpha_x < \alpha_y$ with $\alpha_x = \alpha_y > 0$. In this condition, the birth and death rates of people who use the Limola language are higher than the birth and death rates of those who use other languages. The equilibrium point e_4 for the value $K_x = 0.510, K_y = 0490, \alpha_x = 1.59, \alpha_y = 2, c = 1$ is $e_4 = (0.62, 0.34)$. The behavior of the PR system can be seen in **Figure 4**. The eigenvalues are real and negative, that is $(\lambda_1 = -0{,}941, \lambda_2 = -1.716)$ the behavior of the system around the equilibrium point is asymptotically stable with the type of equilibrium point being sinks. The linearization around the equilibrium point $e_4 = (0.62, 0.34)$ is shown in **Figure 4**.



(a) **(b)**

Figure 4. $\mathbf{K_x = 0.510, K_y = 0490, \alpha_x = 1.59, \alpha_y = 2, c = 1}$ **and Initial Condition (1, 1) (a). Linearization Around** e_4**. (b). System Behavior for** e_4

Based on **Figures 3** and **Figures 4**, if the birth and death rates of residents who use the Limola language are lower or higher than the birth and death rates of those who use other languages, the number of people who use the Limola language decreases than people who use other languages too. But the number of declines is relatively smaller compared to the first case.

This third case is very interesting to analyze, where although the birth and death rates of residents that use the Limola language are greater than the birth and death rates of people who use other languages, the use of the Limola language is still reduced. This is because the language used to communicate as a child as an indicator of the carrying capacity of the Limola language, is very small. Families may not always find it practical to foster their children in a minority language in low-vitality environments **[23]**. See **Table 1**.

The use of language used by parents when communicating with their children is more dominant in Indonesian, which is 49%. Only 29% of parents use Limola, and the remaining 22% use a mixed language of Indonesian, Bugis, Limola, and Tae'. The same thing is when the children communicate with their parents, 82% use the Indonesian language. Only 3% use the Limola language and the remaining 15% of the children mix Limola, Indonesian, Tae', and Bugis languages when talking to their parents. This number shows that intergenerational language transmission is very small. Communication that parents do with their children using local languages is a way of passing on the language to the next generation. So that when parents communicate with local languages to their children, their children will use that language, so that language will always be used in the family environment. These findings were strengthened by **[24]** and **[25]**, which parents' language is positively correlated to children's language. Languages and communities are also changing and this change has an impact on how language and culture are produced in children **[26]**.

Intergenerational language transmission is one of the indicators of the vitality of the language formulated by UNESCO **[27]**. The other indicators are the absolute number of speakers, the proportion of speakers to the total population, trends in the domain of language use, responsiveness to new domains and media, materials for language and literacy education, language policies by governments and institutions, including official status and usage, public attitudes speakers of their language and the amount and quality of language documentation. The condition of each indicator is shown in **Figure 5**.

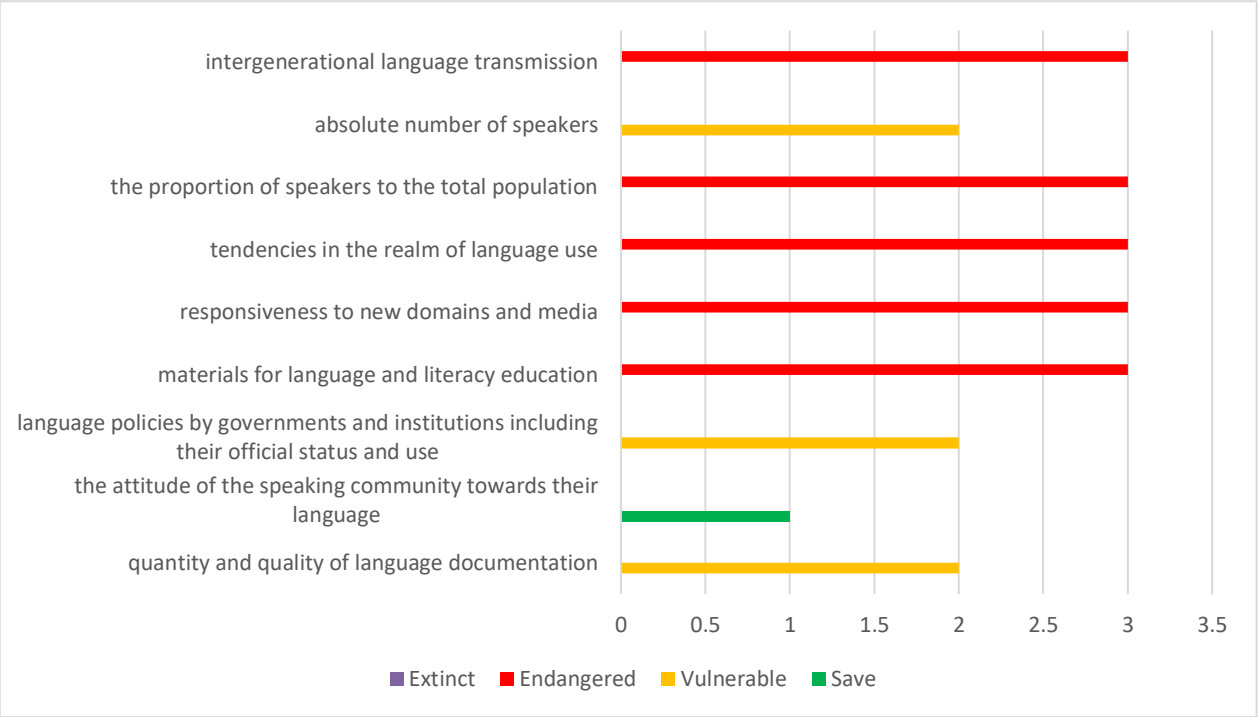


Figure 5. Condition of Limola Language by Indicator of UNESCO

4. CONCLUSIONS

This research has shown the vitality of the Limola language using the Pinasco and Romanelli model and the nine indicators from UNESCO. The number of the Limola language speakers, alongside other languages in the village of Sassa, can still coexist in a balanced and stable. This is evident from the lower level of support for languages other than Limola among the residents of Sassa compared to the growth rate of Limola language speakers. However, if this level of support decreases, the Limola language could be at risk of extinction. This is indicated by the fact that only one of the nine vitality indicators for languages by UNESCO is at a safe threat level.

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