Municipal Policy Design support for artisanal gold mining by System Dynamics Simulation

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Abstract: *Gold mining is a large and old problem in Peru. This situation was getting worse in the last decade because of the increase of gold price and the lack of efficient control by the municipal government. This research adopts system dynamics simulation to help the predictions of social and economic behaviors of communities. By using both simulation results and the knowledge of municipal officers, it is expected that decisions of policy making are improved.*

Keywords: Artisanal gold mining, Policy Making, Mercury, simulation

1 Introduction

Artisanal miners expand their activities from just extract ore to produce unrefined gold using more advance technologies as the use of mercury which causes a great impact into the water bodies and environmental resources.[1]

The complexity of the socio-economic impact of the AGM and the local community, and lack of efficient control by the municipal government allow the continuous degradation of the local population health and the environment surroundings the mine.[2]

The objective of this research is to reduce the mercury contamination in Peru due to the artisanal gold mining. In order to accomplish that objective is proposed a system dynamic model of the AGM system to support municipal policy decision making. The model will take in consideration two effects: Technology Improvement and education impact.

2 Methodology

The proposed methodology will include 2 stages: model development and policy exploration.

A general model is developed, this model simulates the AGM process and will have as an output the economic impact and health impact caused by the Gold mining. The policy exploration will evaluate different policy scenarios using the system dynamics model in order to find potential solutions for the mercury pollution issue. The proposed methodology is shown in Fig. 2-1.

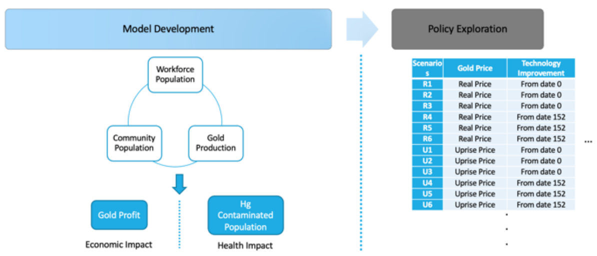

Fig. 2-1 Proposed Methodology

2.1 Model Development

Important variables of the model are *Number of AGM population*, *Gold production*, *Mercury loss* and *Health impact*. The model will include these variables but due to the complexity of the system, the model is divided in multiple parts to be easily understandable.

The first part of the model is created to estimate the workforce needed on the artisanal gold miner's process; this part will focus on estimate the demand of workers in order to calculate the Number of AGM Population.

The second part is in charge to calculate the gold production. In this part of the model will calculate the gold production and the mercury loss using the Number of AGM Population previously calculated on the estimated workforce model part.

Last part is focused to calculate the community population, this part of the model will include the effect of health impact on the Number of AGM population, using the previously gold production model part.

It is very clear to see that each model will affect the other one as shown in Fig. 2-2, this because the behavior analysis of the system has two feedback loops, and the model will follow the same conduct.

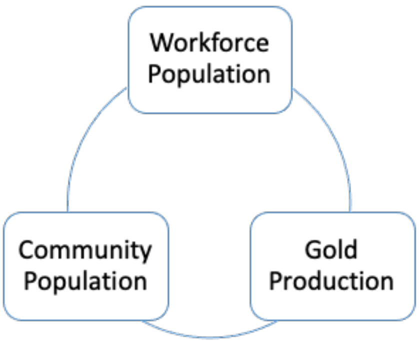

Fig. 2-2 Top Level Structure Model

2.3 Policy Scenario

For the policy exploration, two effects will be evaluated: Education effect and Technology improvement.

Education Effect

Intensive mercury education is necessary in order to raise environmental awareness in artisanal gold mining communities.

Technology Improvement

Technologies to reduce mercury contamination is a broadly subject. One of the strategies to attack this problem is related with air quality control. In AGM, there are few measures taken to prevent mercury exposure. The mercury metal and amalgams are handled directly by hand, and heating the amalgam is often done without proper ventilation.

3 Case Study

3.1Policy Scenario Parameter

For this case study, we have selected 6 different scenarios as a combination of gold price input, Technology improvement and education effect implementation time. The Table 3-1 List of policies scenariosTable 3-1 represents the scenario list.

Table 3-1 List of policies scenarios

Scenarios	Gold Price	Technology Improvement	Education Effect
R1	Real data	Yes	from start
R2	Real data	Yes	intervals
U1	Uprising	Yes	From start
U2	Uprising	Yes	Intervals
D1	Downfall	Yes	from start
D2	Downfall	Yes	intervals

The parameter Gold Price has three different behavior: Real data, Uprising and Downfall. Real data simulate real gold price from January 2000 until December 2019. Uprising gold price simulate a high price scenario where the gold price increment higher than any previous gold price value registered. Downfall gold price scenario is a "pessimistic" scenario where the gold price decrement its value to a minimum amount where is not rentable to continue working in gold mining.

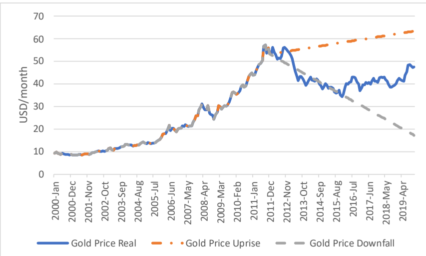

Fig. 3-1 Real vs Uprise vs Downfall Gold Price

3.2 Output Analysis

Uprising scenario will be evaluated
U1 and U2 policies shows an increment in gold profit after the uprising start to working. U2 present a lower profit because of the extra cost of the education program as shown in Fig. 3-2

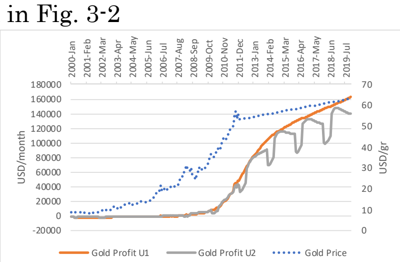

Fig. 3-2 Real Gold Price policies scenarios Gold Mining Profit

Fig. 3-3 shows the comparison between policies U1 and U2 there is a reduction of contaminated population due to the education policy. There is still an increment of Hg contaminated population due to the expansion of the AGM population.

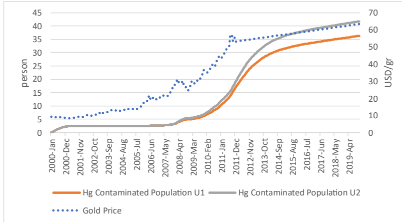

Fig. 3-3 Mercury Contaminated Population Policy U

policies U1 and U2 shows an increment of AGM population as expected of gold price trend as shown in Fig. 3-4.

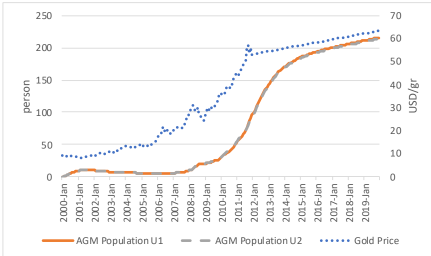

Fig. 3-4 Increment AGM Population Ratio Policy D

4 Conclusion

The case study mainly works as a test to tried different potential policy making solutions in mining policy. The gold price seems to be the main driven of the system, but it is possible to change the behavior with different policies as improvement of education or implementation of new technologies. These observations have implications on how the government should decide to invest its resources, as an investment in infrastructure or training for the community.

As a result of the policy exploration, improvement of technological equipment and the adoption of technologies to reduce contamination by mercury is feasible. These technological developments should also contribute to the mitigation of the environmental impact that would lead to a reduction in social conflict.

5 Reference

[1] A. J. Bebbington and J. T. Bury, "Institutional challenges for mining and sustainability in Peru," *Proc. Natl. Acad. Sci. U. S. A.*, vol. 106, no. 41, pp. 17296–17301, 2009, doi: 10.1073/pnas.0906057106.

[2] L. Bird and N. Krauer, CASE STUDY: Illicit Gold Mining in Peru. 2017.