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Application of a Genetic-Fuzzy FMEA to Rainfed Lowland Rice Production in Sarawak: Environmental, Health, and Safety Perspectives

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ABSTRACT Rainfed lowland rice is the most popular choice for rice cultivation in Sarawak, Borneo. In general, rice production in Sarawak consists of seven phases, namely, preparing land, establishing crop, transplanting, managing crop, harvesting, post-harvesting, and milling. Most farmers in Sarawak depend on indigenous knowledge and experience for rice cultivation. In this paper, an improved fuzzy Failure Mode and Effect Analysis (FMEA) with genetic algorithm-based design of fuzzy membership functions and monotone fuzzy rules relabeling is employed as a knowledge-based tool for risk analysis and assessment pertaining to rice production in Sarawak. The specific focus is on issues related to the environment as well as health and safety of farmers and consumers. With the support from the Sarawak Government, we analyze useful data and information pertaining to various rice fields from experienced farmers to develop the fuzzy FMEA model. Specifically, we develop fuzzy FMEA to inculcate the best practices for farmers to improve yield and enhance food safety. Through this study, we identify that musculoskeletal disorders due to bad postures is the most noticeable occupational health hazard; as a result, new techniques and tools are invented and introduced to mitigate this risk. In summary, this is a new attempt to implement a quality and risk assessment tool that contributes towards enhancing rice productivity in Sarawak, and modernizing the local agricultural sector.

INDEX TERMS Borneo, fuzzy Failure Mode and Effect Analysis, genetic algorithm, monotone fuzzy rule relabeling, rice production, safety, health, and environment

I. INTRODUCTION

Rice, or scientifically known as Oryza Sativa (Asia rice) or *Oryza Glaberrima* (Africa rice), or commonly known as *padi* is one of the most important staple food sources worldwide for centuries [1]. It is also the dominant cereal crop in most Asian countries. Approximately 90% of rice production comes from Asia, and rice contributes approximately 35% to 60% of calories consumed by 3 billion Asian [1]. In European countries, the consumption of rice has significantly increased in the last few years, due to immigration and diversification of diets [2]. Nowadays, people in Sarawak (located in the Borneo Island) still depend on imported rice, since the governance of Brooke (1841-1941) [3]. There are three sub-species of *Oryza Sativa* [4]: (i) non-sticky and slender grain (Indica); (ii) sticky and short rounded grain (Japonica or Sinica); (iii) large bold grain (Javanica). Indica grows in monsoon climates such as in the south and Southeast Asia; Japonica usually grows in moderate climates such as in China; while Javanica is the intermediate species originated from the hilly areas of Southeast Asia such as in Indonesia [4]. Note that, *padi* means rice in the Malay language [5], while paddy, which is derived from *padi*, is synonymous to rice soil [5].

Rice usually grows under diverse conditions, ranging from upland aerobic conditions to irrigated anaerobic conditions, including drought prone and flood-prone eco-systems [6]. According to the International Rice Research Institute (IRRI) [2], [7], [8], rice generally grows in four eco-systems: (i) upland or dryland; (ii) rain-fed lowland (or wet rice); (iii) irrigated lowland or flooded; (iv) deep-water or floating. In practice, a rice field can be categorized into either irrigated (water supply is controlled), or rain-fed (water supply is uncontrolled) [9]. According to the Department of Agriculture, Sarawak (hereafter abbreviated as DOA) [10] and the Ministry of Modernization of Agriculture, Native Land and Regional Development, Sarawak (hereafter abbreviated as MANRED) [11], rice in Sarawak is mainly cultivated in three different ecologies: (i) rain-fed upland; (ii)