International Journal of Knowledge and Systems Science
Volume 15 • Issue 1

Multi-Objective Job Rotation in Rice Seed Harvesting With Equitable Injury Risk and Cost Allocation

Waranyoo Thippo, King Mongkut's University of Technology Thonburi, Thailand
Chorkaew Jaturanonda, King Mongkut's University of Technology Thonburi, Thailand*
Sorawit Yaovasuwanchai, King Mongkut's University of Technology Thonburi, Thailand
Charoenchai Khompatraporn, King Mongkut's University of Technology Thonburi, Thailand
Teeradej Wuttipornpun, King Mongkut's University of Technology North Bangkok, Thailand
https://orcid.org/0000-0001-9972-0566
Kulwara Meksawan, Chulalongkorn University, Thailand

ABSTRACT

This article presents a non-linear multi-objective optimization model with four different objectives for manual rice seed harvesting, aiming to ensure members' fairness and mutual benefits for a group of rice field owners responsible for seed planting and a group of workers tasked with harvesting rice seeds. The harvesting plan primarily focuses on minimizing the average injury risk to workers and secondarily balances this risk among workers. Simultaneously, the model seeks to minimize and equitably allocate wage costs for rice field owners. Worker characteristics, including age, gender, and body mass index are considered to influence injury risk differentially. The optimal solution involves rotating workers to different rice stalk types in several fields, all within appropriate work and rest periods. This approach serves to prevent musculoskeletal disorders and fatigue among the workers while helping rice field owners reduce their costs. This collaborative planning has the potential to enhance sustainability within the farming community.

KEYWORDS

Augmented Epsilon Constraint, Collaborative Planning, Equitable Injury Risk Allocation, Job Rotation, Multi-Objective Optimization, Rice Seeds Harvesting

1. INTRODUCTION

Rice has long been a crucial plant in the global economy. Currently, over half of the world's population consumes rice as their main dish. Thailand has consistently been recognized as a kitchen of the world or global food production hub, particularly for rice, and is among the top three rice-exporting countries (World Data Atlas, 2020). Therefore, it is of paramount importance the rice produced in Thailand be of high quality; and the cultivation of rice in this country, especially for export, should be given

DOI: 10.4018/IJKSS.334124

*Corresponding Author

special concern. One essential factor in ensuring high-quality rice is the careful management of rice seeds. Rice seeds can be categorized into three generations or stages. The first-, second-, and third-generation rice seeds are called foundation rice seed, registered rice seed, and certified rice seed, respectively (National Bureau of Agricultural Commodity and Food Standards, 2015). The progeny of the rice breeder seed is called foundation rice seed. Later, the rice produced from the foundation rice seed is called registered rice seed. These registered rice seeds are distributed to a dedicated group of field owners to cultivate the seeds into certified rice seeds. The certified rice seeds are distributed to rice field owners nationwide, eventually leading to the production of commercial rice for domestic consumption and export.

The focus of this study is photoperiod-sensitive rice, known for its sensitivity to the timing of harvesting, which significantly impacts its quality. For photoperiod-sensitive rice, which is classified as a short-day plant, the highest seed quality occurs four to five weeks after the panicle becomes fully visible during the heading stage. Harvesting must be completed during the final two weeks, or 14 days, of this peak period; otherwise, seed quality deteriorates (Itani et al., 2004). Preserving the purity of rice seeds is crucial for maintaining the authentic characteristics of each rice variety. Traditionally, rice seeds are harvested by hand, but nowadays combine harvester machines are widely used. Traditional, or manual, harvest requires workers to use a hand-held agricultural tool to cut the rice stalks. Even though the combine harvester machine saves a great deal of time over the traditional harvest method, it poses a higher risk of cracking or damaging rice seeds and of unintentional cross-breeding if not cleaned properly (Medrano et al., 2016), resulting in a loss of purity in rice seeds. However, manual labor in agricultural work poses health risks to workers. According to a report by the US Bureau of Labor Statistics (2019), workers in agricultural careers are consistently in the top-ten rank for injury and illness probabilities. Thai rice field workers, as reported by Sombatsawat et al. (2019), often experience symptoms of injury during and after fieldwork, including back and neck pain. As mentioned earlier, the harvest of photoperiod-sensitive rice must be completed within 14 days, additionally, uneven land and varying rice stalk conditions (upright, lodged, and inundated), lead to different levels of work difficulty and injury risk for workers, depending on their working postures, as displayed in Figure 1. Workers in inundated fields, where they must bend their bodies frequently, face the highest risk of physical injury (Taechasubamorn et al., 2011) and fatigue (Pirmoradi et al., 2017). Fatigue from working can affect work efficiency (Ahmed et al., 2017), leads to work-related musculoskeletal disorders (WMSDs), and later can result in an incapacity for work.

WMSDs encompass illnesses and discomforts affecting the musculoskeletal system, in which the causes are multifactorial (World Health Organization, 1985; Yassi, 2000). A high prevalence of

Figure 1. Working postures with three risk stalk types

Upright rice stalks | Lodged rice stalks | Inundated rice stalks