GLOBAL RESEARCH IN ENVIRONMENT AND SUSTAINABILITY

Volume 1, Issue 10, December 2023

GRES

TABLE OF CONTENTS

EDITORIAL BOARD

DISCLAIMER

All the manuscripts are published in good faith and intentions to promote and encourage research around the globe. The contributions are property of their respective authors/owners and Global Research in Environment and Sustainability (GRES) is not responsible for any content that hurts someone's views or feelings. Authors are responsible for if any plagiarism is found in published material.

Global Research in Environment and Sustainability
December 2023, Vol. 1, No. 10, pp. 01-06.

Advisory Services and the Diseases Case Among the Livestock: A Case Study of Muzaffargarh, Punjab Pakistan

Mohsin Raza[1], Badar Naseem Siddiqui[2], Muhammad Saleem[3], Shoukat Ali[4], Muhammad Asghar[5].

1, 2 Department of Agriculture Extension, Pir Mehr Ali Shah Arid Agriculture University, Rawalpindi

3,4,5 Institute of Agriculture Extension, Education and Rural Development, University of Agriculture Faisalabad

Abstract:
Livestock plays a significant role in the Pakistani agricultural sector, contributing approximately 56.3% to the agricultural value added. With over 35 million people engaged in this sector, it contributes nearly 11% to the country's GDP. Pakistan boasts a substantial population of livestock and is ranked among the top herd owners globally. Despite this, the country still imports livestock products from various countries. The current study aims to investigate the advisory services provided by the livestock department. The study's sample comprised farmers and Veterinary Field staff. The study results revealed that veterinary field staff provided advisory services through home visits, demonstrations, group meetings, and field tours, as reported by the veterinarians. Additionally, the veterinary staff reported providing various services at the farmers' doorsteps, including animal treatment, capacity building for livestock farmers, as well as insemination and vaccination of animals. However, many farmers expressed dissatisfaction when asked about the services rendered by the field staff at their doorstep. Farmers also reported the occurrence of various diseases in their animals, such as Anthrax, Black Quarter, Milk Fever, Mastitis, and Bovine Babesiosis etc.

Keywords: Advisory, Livestock, Diseases, Services

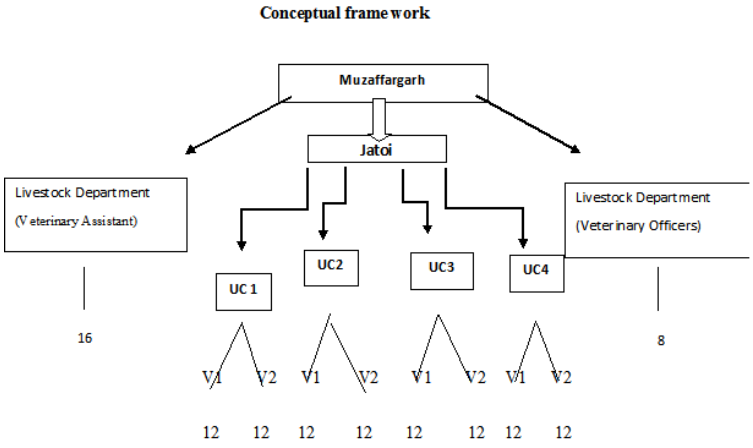
INTRODUCTION

Livestock sector plays a vital role in Pakistan's rural economy, with more than 8 million rural households involved in livestock farming, generating 35 to 40% of their earnings from this sector. The livestock industry has become the dominant force in agriculture, making up around 62.68% of agricultural value added and contributing 14.36% to the overall national GDP in the fiscal year 2023. There is the large herd of animals in the country but the production is less might be due the less efficient breeds, disease attack etc. Losses in livestock sector due to animals' disease such as Lumpy Skin disease attack during 2021, caused a high economic loss of the farming community. The total number of cases in Pakistan were 221,399, with 38,092 animal deaths and the mortality rate was 0.0917 percent (Govt. of Pakistan, 2023). Livestock Extension services encompass education on disease prevention, early detection, and proper diagnostic and treatment protocols. They also emphasize biosecurity measures, vaccination programs, and compliance with regulations to reduce disease risks. Advisors play a crucial role in monitoring disease trends, reporting outbreaks, and disseminating information about the latest research and innovations in livestock health. Additionally, they help livestock owners assess the economic impact of disease outbreaks and provide continuing education to ensure informed decision-making for the well-

being of livestock and the sustainability of livestock-related industries (Degu, 2012). But advisory services in Pakistan regarding livestock management are indispensable for mitigating the impact of disease cases. One can this while keeping in view the livestock production of Pakistan is far below than that of developed countries, instead of having a large herd size (Idrees et al., 2007). The major reason behind the low livestock productivity is non availability of livestock extension services. It also leads towards the less adoption of the improved livestock technology. For the economic development it is necessary to develop and sustain the livestock sector and it is only possible through the adoption of latest livestock related technologies. The adoption of the latest information by the farmers depends upon the efficiency of the extension filed staff. More efficient the staff is, more will be the adoption (Ali, 2018). Livestock extension services are instrumental in reducing disease prevalence among animals by offering valuable guidance and knowledge to farmers. These services educate farmers about disease prevention, vaccination, and biosecurity measures, enabling them to proactively protect their livestock from illnesses. Extension agents also facilitate early disease detection, prompt treatment, and responsible medication use, which collectively contribute to minimizing the impact of diseases on animal health and agricultural sustainability (Coetzee et al., 2005). In Pakistan different initiatives were taken from time to time by the livestock department and by private organization to facilitate the livestock farmers. As the farmers are illiterate and they have a little bit knowledge about the latest livestock management practices. Therefore, it is the duty of Livestock extension field staff to educate the farmers and to bring the positive change in the behavior of the farmer regarding the adoption of innovative method of livestock farming. Livestock and Dairy Development Department (Punjab) is mandated for rendering the advisory and health services at the door step of the farmers' extension field staff.

METHODOLOGY

The district of Muzaffargarh was purposefully selected for the research study due to its large population of livestock, including cows, buffaloes, sheep, goats, and camels. This district comprises four tehsils: Muzaffargarh, Kotadu, Jatoi, and Ali Pur. Among these tehsils, Jatoi was chosen conveniently. Jatoi consists of 16 Rural Union Councils (RUCs), and from these, four RUCs were randomly selected. Within these four selected RUCs, two villages were also randomly chosen, resulting in a total of eight villages being included in the study. To collect data, twelve livestock farmers (10 males and 2 females) were randomly selected from each of these eight villages, leading to a sample size of 96 farmers. Additionally, 16 veterinary assistants and 8 veterinary officers were randomly selected from the selected Tehsil (Jatoi).



RESULTS AND DISCUSSION

Socio-Economic Characteristics of the Respondents

Socio-economic attributes of veterinary Field Staff			Farmers Socio-economic attributes		
Age	f	%	**Age**	f	%
25-35 years	5	20.8	25-35 years	5	20.8
36-45 years	17	70.8	36-45 years	17	70.8
46 or above	2	8.3	46 or above	2	8.3
Education			**Education**		
Diploma	16	66.7	Illiterate	16	16.6%
Degree	8	33.3	Primary	30	31.2%
Gender			Middle	20	20.8%
Male	24	100	Matric	17	17.7%
Female	0	0	Up to matric	13	13.5%
Working Experience (years)			**Gender**		
1-10	14	58.3	Male	80	83.3%
11-20	8	33.3	Female	16	16.7%
21-30	2	8.3	**Livestock farming Experience (years)**		
Background			1-5 years	7	7.2%
Urban	0	0	6-10 years	9	9.3%
Rural	24	100	11-15 years	23	23.9%
			Up to 15 years	57	59.3%

The table presents a comparison of the socio-economic attributes between the veterinary field staff and the farmers. In terms of age distribution, both groups exhibit a similar pattern, with the majority falling within the age brackets of 36-45 years, indicating an experienced cohort actively engaged in the veterinary and agricultural sectors. However, the distribution of educational backgrounds differs significantly, with the veterinary field staff predominantly holding diplomas or degrees, while the farmers vary widely from being illiterate to having completed education up to the primary or matric level. Gender distribution shows a significant male dominance among both the veterinary field staff and the farming community, with a proportion of 100% and 83.3%, respectively. The working experience of the veterinary staff ranges between 1-30 years, demonstrating a diverse range of expertise within the field, while the farmers' livestock farming experience is concentrated within the 1-15 years range, indicating a relatively newer cohort involved in agricultural practices. Additionally, the background of the veterinary staff appears to be predominantly rural, suggesting a close connection to agricultural communities, whereas the farmers' background does not provide specific urban or rural distinctions. Overall, the data highlights the diverse socio-economic characteristics within both the veterinary and farming sectors, underscoring the need for targeted policies and initiatives to address the varied needs and experiences of these crucial stakeholders in the agricultural landscape.

Extension Teaching Methods Adopted by The Veterinary Staff and Reported by Farmers

Adopted by Veterinary Field Staff				Extension Method	Reported by Farmers					
Yes		No			1		2		3	
f	%	f	%		f	%	f	%	f	%
24	100	0	0	**Home visit**	71	73.9	25	26.0	0	0
24	100	0	0	**Cattle farm visit**	59	61.4	37	38.5	0	0
20	83.3	4	16.7	**Demonstration**	64	66.6	32	33.3	0	0
24	100	0	0	**Group Meeting**	49	51.0	47	48.9	0	0

24	100	0	0	**Field Tour**	80	83.3	16	16.6	0	0
12	50	12	50	**Pamphlets**	13	13.5	32	33.3	51	53.3
14	58.3	10	41.7	**Radio**	0	0	0	0	96	100
13	54.1	11	45.9	**Television**	30	31.2	32	33.3	34	35.4

1= Frequently, 2= Occasionally and 3= Rarely

The table provides an insightful comparison of the various extension methods adopted by Veterinary Field Staff, as well as the corresponding feedback reported by the farmers. The data showcases the distribution of these methods based on the frequency of their adoption, categorized as "Frequently," "Occasionally," and "Rarely," denoted by the numerical values 1, 2, and 3, respectively. A key observation from the data is the prevalence of "Home visit" and "Field Tour" as the most frequently adopted extension methods by the Veterinary Field Staff, both reporting 100% adoption rates. This indicates the significant role of personalized and on-site interactions in effectively delivering veterinary services and advice to the farmers. Additionally, "Cattle farm visit" and "Demonstration" also demonstrate high adoption rates, suggesting their importance in providing hands-on guidance and practical training to farmers. Moreover, the data indicates a relatively lower adoption of traditional methods such as "Pamphlets," "Radio," and "Television" among the Veterinary Field Staff. However, it is noteworthy that these methods seem to have a higher reported impact from the farmers' perspective, particularly the "Radio" and "Television" programs, with 100% adoption for the latter. This implies the potential effectiveness of mass communication channels in disseminating critical information and education to a wider audience within the farming community. In the context of a research paper, this data serves as a crucial point of analysis, highlighting the need for a diversified approach to extension services. It underscores the importance of combining personalized and direct engagement with more widespread and accessible communication channels to effectively reach and educate the farming community. The findings emphasize the significance of leveraging various extension methods in the dissemination of crucial information, thereby enhancing the overall effectiveness of veterinary services and promoting sustainable agricultural practices. Further research could focus on evaluating the impact of these different extension methods on the adoption of best practices and their influence on the overall livestock healthcare and agricultural productivity.

Livestock Services Rendered by Livestock and Dairy Development Department and Reported by Farmers

1= low, 2= Medium, 3= High

Responses of The Veterinarians								**Services rendered by Veterinary Field staff**	**Responses of The Farmers**							
1		2		3		No			1		2		3		No	
f	%	f	%	f	%	f	%	Treatment of animals at the door step	**F**	**%**	**f**	**%**	**f**	**%**	**f**	**%**
10	41.7	3	12	11	45.8	-	-		23	24	10	10.4	21	21.9	42	43.8
8	33.3	14	56	2	8.3	-	-	Capacity building of livestock farmers	23	24	21	21.9	10	10.4	42	43.8
5	20.8	8	32	11	45.8	-	-	Diagnostic of animals through Mobile Veterinary Labs	09	9.4	21	21.9	3	3.1	63	65.6
11	45.8	2	8	11	45.8	-	-	Mass vaccination of animals at door step	25	26	31	32.3	22	22.9	18	18.8
14	58.3	0	0	10	41.7	-	-	Rendering of insemination service	11	11.5	09	9.4	17	17.7	59	61.2

The presented table provides a comprehensive overview of the responses from both veterinarians and farmers, using a rating scale of 1 to 3, representing low, medium, and high levels of service provision or response. The data reveals various trends in the perceptions and experiences related to different services rendered by the veterinary field staff. Notably, the "Treatment of animals at the door step" and "Rendering of insemination service" received consistently high ratings from both parties, with percentages ranging from 41.7% to 58.3% for veterinarians and 42% to 61.2% for farmers. Conversely, the "Capacity building of livestock farmers" service garnered moderate ratings, ranging from 33.3% to 45.8% for veterinarians and 43.8% to 43.8% for farmers. The "Diagnostic of animals through Mobile Veterinary Labs" received relatively lower ratings, with percentages ranging from 8.3% to 45.8% for veterinarians and 3.1% to 65.6% for farmers. The "Mass vaccination of animals at door step" service demonstrated a mixed response, indicating a medium to high level of engagement, with percentages ranging from 18.8% to 32.3% for farmers and 18% to 45.8% for veterinarians. Overall, the data underscores the importance of tailored strategies to enhance veterinary services, with a specific focus on leveraging technology for diagnostics and ensuring the accessibility of crucial services for livestock farmers. The table presents a comprehensive overview of the prevalence of various diseases among livestock, categorized into four severity levels: Very High, High, Medium, and Low. Upon closer examination, it becomes evident that certain diseases pose a significant health risk to the livestock population. Notably, diarrhea emerges as the most prevalent concern, with 56.2% of cases falling under the "Very High" severity category, indicating a critical and widespread health issue affecting the livestock. Similarly, foot rot and mastitis demonstrate considerable prevalence across all severity levels, with 48.9% and 66.6% falling under the "High" severity category, respectively. Furthermore, diseases such as anthrax, black quarter, and pox exhibit a relatively balanced distribution across severity levels, indicating a consistent presence within the livestock population. On the other hand, diseases such as bovine babesiosis and FMD show a higher prevalence in the "Medium" severity category, suggesting a moderate but persistent challenge for livestock health. Interestingly, certain diseases, including respiratory diseases and wounds, demonstrate a prevalence predominantly in the "Very High" and "High" severity categories, emphasizing the urgent need for effective disease management strategies to safeguard the well-being and productivity of the livestock.

Livestock Diseases Reported by the Farmers in their Animals

Diseases	Very High		High		Medium		Low		Very low	
	f	%	f	%	f	%	f	%	f	%
Anthrax	12	12.5	23	23.9	40	41.6	21	21.8	0	0
Black quarter (black leg)	16	16.6	21	21.8	23	23.9	45	46.8	0	0
Pox	21	21.8	42	43.7	17	17.7	16	16.6	0	0
Milk fever	20	20.8	35	36.4	19	19.7	22	22.9	0	0
Foot root	12	12.5	47	48.9	11	11.4	26	27.0	0	0
Mastitis	11	11.4	53	55.2	17	17.7	15	15.6	0	0
Bovine babesiosis	20	20.8	12	12.5	59	61.4	08	8.3	0	0
Ring worm	31	32.2	38	39.5	11	11.4	26	27.0	0	0
Diarrhea	54	56.2	31	32.2	11	11.4	0	0	0	0
FMD	53	55.2	29	30.2	14	14.5	0	0	0	0
Respiratory disease	54	56.2	31	32.2	11	11.4	0	0	0	0
Wounds	53	55.2	29	30.2	14	14.5	0	0	0	0

1= Very High, 2= High, 3= Medium, 4= Low and 5= Very Low

Overall, the data highlights the complex nature of disease prevalence within the livestock population, underscoring the necessity for robust disease surveillance and proactive health management practices. These findings underscore the critical role of veterinary professionals and stakeholders in implementing targeted disease control measures and preventive strategies to mitigate the impact of these diseases on the livestock industry.

REFERENCE

Ali, A. (2018). Impact of climate-change risk-coping strategies on livestock productivity and household welfare: empirical evidence from Pakistan. *Heliyon*, *4*(10).

Coetzee, L., Montshwe, B. D., & Jooste, A. (2005). The marketing of livestock on communal lands in the Eastern Cape Province: contraints, challenges and implications for the extension services. *South African Journal of Agricultural Extension*, *34*(1), 81-103.

Degu, G. (2012). Assessment of the livestock extension service in Ethiopia: the case of southern region. *International journal of scientific & technology research*, *1*(10), 24-30.

Government of Pakistan (2023). Pakistan Economic Survey. Available at: https://www. finance .gov.pk/survey_2023.html.

Idrees, M., Mahmood, Z., Shafi, M., & Sidique, U. (2007). Performance evaluation of extension services of livestock and dairy development department in district Peshawar (NWFP). *Sarhad Journal of Agriculture*, *23*(2), 519.

Rehman, A., Jingdong, L., Chandio, A. A., & Hussain, I. (2017). Livestock production and population census in Pakistan: Determining their relationship with agricultural GDP using econometric analysis. *Information Processing in Agriculture*, *4*(2), 168-177.

Global Research in Environment and Sustainability
December 2023, Vol. 1, No. 10, pp. 07-18.

Information Dynamics in All Japan Women Championship in High School Soccer 2020 Final

Takeo R. M. Nakagawa

1. Itaya Hyoshiro Institute for Philoophy of Flow, 2-14, Meiko, Hakusan 920-2152 Japan

Abstract:
This paper is concerned with information dynamics in all Japan women championship in high school soccer 2020. The final game has been successfully simulated and modelled in terms of advantage and certainty of game outcome depending on the time. In the data analyses, as evaluation function scores, in addition to goal, it is realized that consideration of shoot, corner kick, or penalty kick are essential, and thus faithful analyses to games have been conducted, where proper choice and assessment of evaluation function scores are carefully made during the games. The refined game information depending on the time, makes possible for supervisor, coach, player or fan to reflect the past game and to prepare for the future game, so that the present analyses add a pedagogical value to activities relating to soccer other than entertainment.

Keywords: Pedagogical Game, Soccer, Evaluation Function Score, Advantage, Certainty of Game Outcome

INTRODUCTION

Serious game is a game designed for a primary purpose other than pure entertainment, enjoyment or fun [1]. Serious games are a sequence of storytelling, where the idea shares aspects with game simulation, but explicitly emphasizes the added pedagogical value of fun and competition. The goal of a serious game is to support learning/training for educator or nurse. Supervisor of a soccer team is educator for the members: Daily activities in soccer support players, for they can learn importance of fairness, cooperation, harmony or patience under the rules. It is known that ultimate goal of soccer is to bring up lady and gentleman, but not to win or to enjoy the game. Thus, it is evident that soccer is a typical serious game.

Making use of game design patterns, Kelle et.al. [2] have implemented information channels to simulate ubiquitous learning support in an authentic situation. Lindley & Sennersten [3]'s schema theory provides a foundation for the analysis of game play patterns created by players during their interaction with a game. Lindley & Sennersten [4] have proposed a framework which is developed not only to explain the structures of game play, but also to provide schema models that may inform design processes and provide detailed criteria for the design patterns of game features for entertainment, pedagogical and therapeutic purposes.

Fullerton et al. [5] argue in favor of 'iterative' design method, which relies on inviting feedback from players early on, where the word 'iterative' refers to a process in which the game is designed, tested, evaluated and redesigned throughout the project. As part of this approach, designers are encouraged to construct first playable version of the game immediately after brainstorming and this way get immediate feedback on their ideas [5]. Play-testing, which lies in the heart of iterative approach, is probably most established method to involve players in design. Play-testing is not

primarily about identifying the target audience or tweaking the interface, but it is performed to make sure that the game is balanced, fun to play, and functioning as intended [5].

Game Ontology Project [6] is distinct from design rules and design patterns approaches that offer imperative advice to designers. It intends not to describe rules for creating good games but rather to identify the abstract commonalities and differences in design elements across a wide range of concrete examples. Rather than develop definitions to distinguish between games and non-games or among their different types, it focuses on analyzing design elements that cut across a wide range of games. Its goal is not to classify games according to their characteristics and/or mechanics [7] but to describe the design space of games.

Knowledge about game designs and game play patterns has grown fairly well, but little advancement has been made to clarify game progress patterns, which denotes how information of game outcome varies depending on time [8,9]. Currently the information dynamic model [8, 9], only makes it possible to treat and identify game progress patterns depending on time. The usefulness of the information dynamic model has been well documented, and successfully applied to American football [14], baseball [9], effect of medicine [10], soccer [11], shogi [13], or judo [8]. On the contrary, von Neumann's game theory [15], for example provide only a few outcomes due to each the decision by players.

The information dynamic model [8, 9] has been applied to soccer [11], in which only goal(s) is considered as the evaluation function score. However, it becomes clear that number of goal(s) is normally too few to conduct adequate analyses for soccer games, so that it is necessary to seek for the other candidate(s) of the evaluation function score to refine the analyses.

Main purpose of the present study is to simulate and model a soccer game, 9th all Japan High School Women Soccer Championship in Noevia Stadium Kobe on 10th January 2021 to support supervisor, coach, player or fan, in terms of advantage, certainty of game outcome together with the information dynamic model.

METHOD OF ANALYSES

For clarity, elemental procedures for obtaining the advantage α, certainty of game outcome ξ, and uncertainty of game outcome ς will be explained by using a soccer game between teams A and B.

The advantage α is defined as follows: When the total goal(s) of the two teams at the end of game $GT \neq 0$,

$$\alpha = [GA(\eta) - GB(\eta)]/GT \quad \text{for} \; 0 \leq \eta \leq 1, \tag{1}$$

where $GA(\eta)$ is the current goal sum for team A(winner), $GB(\eta)$ is the current goal sum for team B(loser), and η is the normalized time, which is normalized by the total time.

When $\alpha > 0$, team A (winner) gets the advantage against team B (loser) in the game, while when $\alpha < 0$, team B (loser) gets the advantage against team A(winner). It is certain that when $\alpha = 0$ the game is balanced. Note that goal is only one of the evaluation function scores in soccer, but in addition to goal, shoot, penalty kick, free kick and corner kick are candidates of the evaluation function score. It is critical how assessor(s) chooses and assesses the evaluation function score

during the game, as to be discussed. When the total goal(s) of the two teams at the end of game GT = 0, α=0 for $0 \leq \eta \leq 1$

The certainty of game outcome means what extent the game outcome (i.e., win or loss) is certain depending on time during the game, and the extent is given by the normalized value ranging from 0 to 1. The word 'certainty' is replaceable with 'probability' without loss of generality, but the accustomed word may be preferable. The certainty of game outcome ξ during the game is defined as follows: When the total goal(s) of the two teams at the end of game GT ≠ 0,

$$\xi = |GA(\eta) - GB(\eta)|/GT \text{ for } 0 \leq \eta < 1 = 1(\text{normal game}) \text{ or } 0(\text{draw game}) \text{ for } \eta = 1. \quad (2)$$

At η=1, ξ is assigned to the value of 1, for at the end of game the information on the game outcome must be 100%. The reason why we take the absolute value of the advantage α to get the certainty of game outcome ξ for $0 \leq \eta < 1$ is that ξ is independent of the sign of α. As far as the absolute value of the advantage α increases (decreases), the certainty of game outcome ξ must increase (decrease). In case of draw game, ξ may be assigned to the value of 0 at the end of game η=1. When the total goal(s) of the two teams at the end of game GT= 0, ξ=0 for $0 \leq \eta \leq 1$.

The uncertainty of game outcome ς during the game is defined as follows

$$\varsigma = 1 - \xi. \quad (3)$$

This equation denotes that the current uncertainty of game outcome ς can be obtained by subtracting the current certainty of game outcome ξ from value of 1. Keeping in mind the forgoing elemental procedures to obtain the advantage α, and certainty of game outcome ξ, it may be straight forward to apply them to actual soccer games. In soccer, goal must be as one of evaluation function scores, for it is critical factor for the game. However, there must be the other candidates such as shoot, corner kick, penalty kick, or free kick. In computer chess, evaluation function score for each of the moves has been successfully assessed by a computer based on objective human evaluation function scores that are adopted for the data analyses of human and computer interaction in shogi between Kunio Yonenaga (Shogi Meijin) and Bonkras (Computer Shogi World Champion in 2012) [13].

CASE STUDY

In this section, investigated are a soccer game, which are the Final, Fujieda vs. Sakuyo of the 9th all Japan High School Women Soccer Championship in Noevir Stadium Kobe on 10th January 2021. This part is concentrated with the case study of Fujieda vs. Sakuyo. Table 1 summarizes results of data analyses for the game. The total time is 90 minutes (54,000 seconds), for the Final is 45 minutes half, and the total evaluation function scores are 38, where each of the shoot (including goal case), corner kick, free kick is counted one as evaluation function score in the present analyses. For example, shoot may seem to be very different from corner kick, but if one looks shoot and corner kick from the assessor's view point, they contribute to the game outcome to the same degree sometimes. At this point, it may be worth noting that occasionally a ball kicked from the corner goes into the goal directly. This is because corner kick is treated exactly same evaluation function score as shoot. When only goal is considered as the evaluation function score, few numbers may cause difficulty to analyze the game properly. Table 1 summarizes game records for the Final. In the game, after the kick off by Sakuyo, Fujieda gets the advantage until η=0.190. During this period, Fujieda makes one shoot, but since Sakuyo gets one corner kick at

η=0.209, the game is balanced. However, from η=0.213 to 0.270, Sakuyo attacks to Fujieda, so Sakuyo increases the advantage α with increasing the normalized time η. Then, Fujieda gets corner kick and shoot at η=0.305, and as the result the game is balanced again. From this time, Fujita keeps the advantage against Sakuyo, in such a way that the former increases the advantage α with increasing η until the end of game. This denotes that Fujieda keeps $\alpha > 0.05$, when η> 0.343: For over 65.7% of the total time, α is greater than 0.05. Thus, this game can be defined as non-categorized game, though it might look as one-sided game.

Table 1 Game records for the Final:Fujieda vs. Sakuyo

η	G_A	G_B	G_A-G_B	α	Fujieda	Sakuyo
0	0	0	0	0		
0.19	1	0	1	0.0263	S	
0.209	1	1	0	0		C
0.213	1	2	-1	-0.0263		S
0.216	1	3	-2	-0.0526		S
0.223	1	4	-3	-0.0789	C	
0.27	2	4	-2	-0.0526	S	
0.305	4	4	0	0	C, S	
0.327	5	4	1	0.0263	S	
0.343	6	4	2	0.0526	C	
0.344	7	4	3	0.0789	S	
0.384	8	4	4	0.105	F	
0.393	9	4	5	0.132	S	
0.399	9	5	4	0.105	S	
0.489	10	5	5	0.132	S	
0.499	11	5	6	0.158	C	
0.5	11	5	6	0.158		
0.509	12	5	7	0.184	C	
0.517	13	5	8	0.211	G	
0.535	14	5	9	0.237	C	
0.54	15	5	10	0.263	S	
0.541	16	5	11	0.289	S	
0.578	17	5	12	0.316	G	
0.601	18	5	13	0.342	F	
0.605	20	5	15	0.395	S, S	
0.633	20	6	14	0.368		F
0.7	21	6	15	0.395	G	
0.733	22	6	16	0.421	C	
0.738	23	6	17	0.447	C	
0.742	24	6	18	0.474	S	
0.743	25	6	19	0.5	C	
0.806	25	7	18	0.474		S, S
0.872	26	7	19	0.5	S	
0.891	27	7	20	0.526	S	
0.894	27	8	19	0.5		S
0.933	27	9	18	0.474		S
0.984	28	9	19	0.5	F	
1	28	9	19	1		

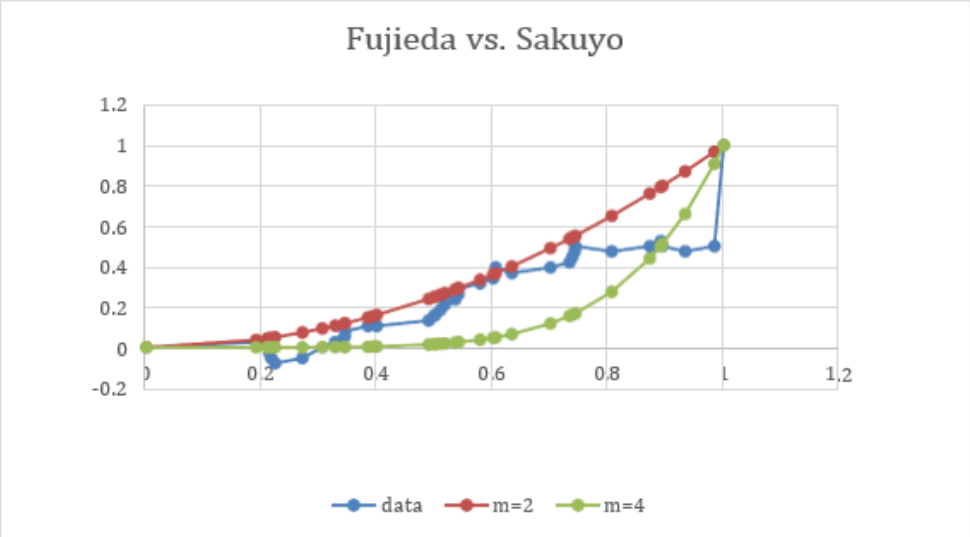


Figure 1: Certainty of game outcome ξ against normalized time η

Figure 1 shows the relation between certainty of game outcome ξ and normalized time η. The certainty of game outcome ξ increases with increasing the normalized time η except for the two points at η=0.209 and η=0.305 in the middle of game.

During this game, several high-level plays have been demonstrated by players, but among them the third goal by the Left Wing (LW) of Fujieda at η= 0.7 is the best: At position A the Left-Wing kicks forward along the solid line, which is the left side of the Full Back (FB) of the opponent team, but she dushes to chase the ball leaving the opponent Full Back behind. Then, immediately after she controls the ball again at position B, she dribbles the ball to set the ball for preparing the ideal shoot at position C. The Left Wing kicks the ball in order to get the goal, and this ball takes her imaged course to go into the far side net of the opponent team goal flying over the Goal Keeper. This goal becomes the third goal of Fujieda against Sakuyo. The present authors are strongly impressed by this goal, for this goal demonstrates her superior creativity, exquisite body balance, excellent skill of shoot and instant adequate decision for play. It is believed that she must be a promising soccer player in Japan.

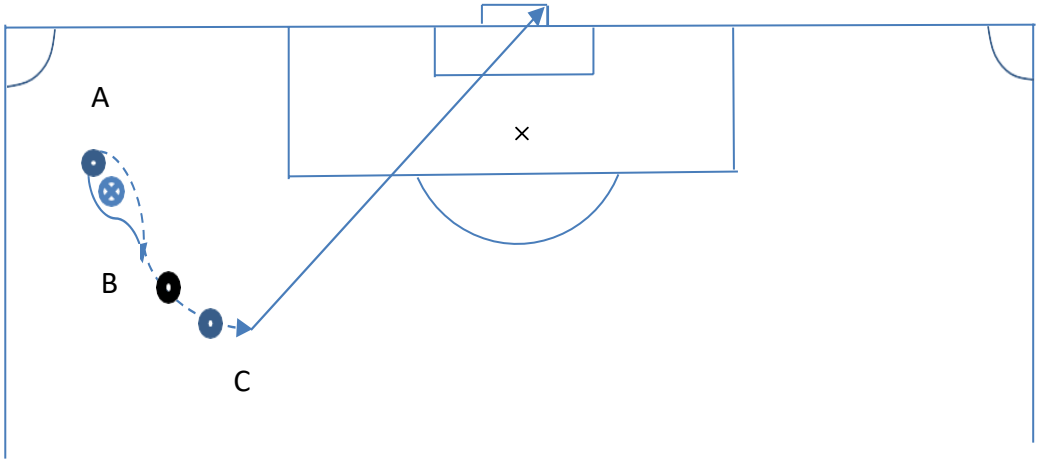


Figure 2: The sketch of the third goal by the Left Wing of Fujieda at η=0.7.
: Left Wing of Fujieda, : Full Back of Sakuyo

DISCUSSION

The Final, Fujieda vs. Sakuyo will be discussed with reference to information dynamic model, which is expressed by

$$\xi = \eta^{m}, \tag{4}$$

where ξ is certainty of game outcome, η is normalized time, and m is a positive real number. For full account of the information dynamic model, refer to Appendix 2. Figure 1 shows the relation between certainty of game outcome ξ and normalized time η, where game data of Fujieda vs. Sakuyo together with two curves of the information dynamic model $\xi = \eta^{m}$, where m= 2, and 4, have been plotted concurrently. It may be interesting to point out the fact that starting from the kick off, this game proceeds almost along with first model curve $\xi=\eta^2$, but from η=0.743, it deviates from this curve to second model curve $\xi=\eta^4$ but without approaching to the later curve, ξ increases with η until the end. Nakagawa & Minatoya [8] has proposed a new notion coined 'game point', which is the cross point between certainty of game outcome ξ and uncertainty of game outcome ς. It is considered that once time exceeds to the game point, one team (or player) gets the safety lead against the other team (or player), and thus it is valuable to discuss the game point in interpreting the game. Let us discuss the effect of Hakusan FC's goal and shoot on the game in terms of game point.

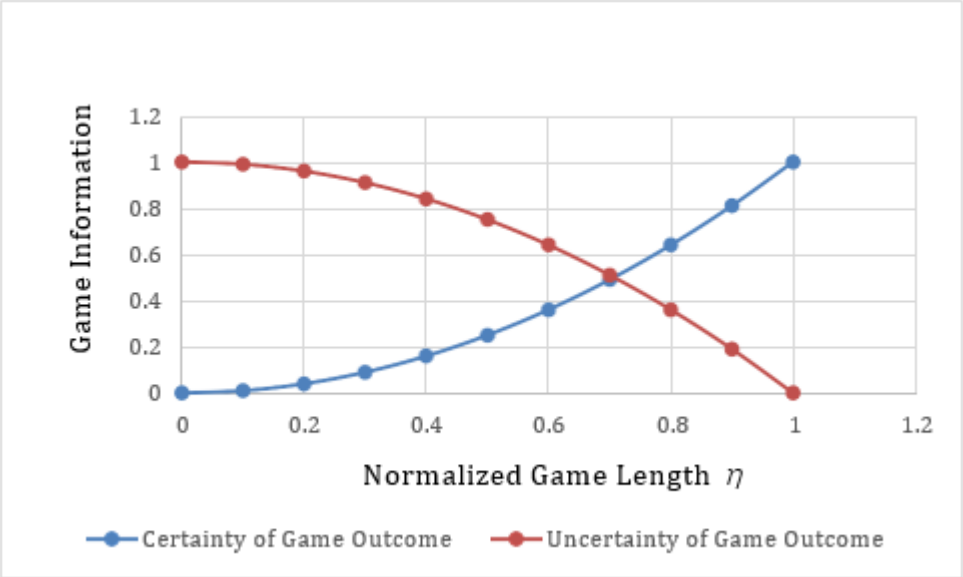


Figure 3: Information of game outcome against normalized time η

Figure 3 shows the relation between information of game outcome and normalized time η, where $\xi=\eta^2$ is the first curve for certainty of game outcome, and $\varsigma = 1 - \eta^2$ is the curve for uncertainty of game outcome. At the game point, certainty of game outcome ξ is equal to uncertainty of game outcome ς, and both of the curves are taking the common value of 0.5. It can be noted in Figure 3 that in this case the game point is at $\eta \approx 0.7$. Thus, if this game can be modelled by the curve $\xi=\eta^2$ from η=0 to 1, the game outcome of Fujieda's win is predicted at about 0.7(70%) of the total time of 1. It is clear that the game point is significant, for once the game passes it, the team that has the advantage can be guaranteed its win in 100 %, while the opponent has no hope to win the game.

Let us now discuss choice and assessment of evaluation function scores in soccer. There is no question that the choice and assessment are critical to do valuable analyses for supervisor, coach, player or fan. Candidates of evaluation function score in soccer may be goal, shoot, penalty kick, free kick or corner kick, but the assessor(s) is required to decide which one should be chosen and counted as the evaluation function score among the candidates. That is, in case of penalty kick match, evaluation function score of a successful kick must be counted as one, while that of an unsuccessful kick is counted as zero. Furthermore, if course of the ball is out of the goal mouth, and/or speed of the kicked ball is too slow, evaluation function score of a shoot or free kick may be counted as zero. On one hand, even if course of the ball is out of the goal mouth, a strong shoot and/or free kick towards the goal mouth may be counted as one. Whether a free kick is counted as evaluation function score or not, also depends on the case that it is direct or indirect. A direct free kick should be treated as a shoot, but an indirect free kick may not. In case of corner kick, it is known that sometimes the kicked ball goes into the goal directly either by the rotation of ball, wind, or own goal. When the kicked ball reaches at or near the goal area, it is, therefore, necessary to judge carefully whether it should be counted one or zero as evaluation function score. It is realized that though in soccer goal is quite important and unique, consideration of the other candidates such as shoot, penalty kick, free kick or corner kick is essential for simulating and modelling the game faithfully.

It may be interesting to point out that the information dynamic model possesses a potential to predict game outcome, where information of game outcome is expressed as depending on time. Using initial conditions such as team (player)' ranking, and/or record, value of the parameter 'm' of the information dynamic model in (4) may be obtained before a game starts. It is clear that once this value is provided, the game will proceed along one of the model curves as plotted in Figure 5 from the start to the end. The information dynamic model is applicable to predict future trends in social problems such as GDP (Gross Domestic Product), population, temperature or effect of medicine, or educational attainment, where current information such as an inclination angle of the relevant curves is critical.

CONCLUSIONS

In this section, new knowledge and insights obtained through the present study have been summarized as follows, A soccer game have been successfully simulated and modelled in terms of advantage and certainty of game outcome depending on time. In the data analyses, as evaluation function scores, in addition to goal, it is realized that consideration of shoot, corner kick, or penalty kick are essential, and thus faithful analyses to the game have been conducted, where proper choice and assessment of evaluation function scores are carefully done during the game. The refined game information depending on the time makes possible for supervisor, coach or player to reflect the past game and to prepare for the future game by reviewing the time history of the advantage, certainty of game outcome or game point in the past games, so that the present analyses add a pedagogical value to activities in soccer other than entertainment. This game has been defined as non-categorized game, though it might look as one-sided game. Particularly, it is featured that the third goal of Fujieda is remarkable, so that one of the soccer authorities considers the goal getter, Left Wing of Fujieda, is a promising woman player in WE league, which is the professional Women soccer league, to start this autumn in Japan.

It is suggested that the information dynamic model possesses a potential to predict game outcome before its start.

REFERENCES

[1]. Chen, S., Michael, D. Serious Games: Games that Educate, Train and Inform. USA, Thomson Course Technology, 2005

[2]. Kelle, S., Börner, D., Kalz, M., Specht M. Ambient displays and game design patterns. In WC-TEL710 Proc. of the 5th European Conference on Technology Enhanced Learning Conference on Sustaining TEL from innovation to learning and practice, 512-517, Springer-Verlag, Berlin, Heidelberg 2010.

[3]. Lindley, C.A., Sennersten C.C. Game play schemes: from player analysis to adaptive game mechanics. International Journal of Computer Games Technology, 7 pages, Article ID216784, 2008

[4]. Lindley, C.A., Sennersten C.C. A cognitive framework for the analysis of game play: tasks, schemas and attention theory. In Proc. of the 28th Annual Conference of the Cognitive Science Society, 13 pages, 26-29 July, Vancouver, Canada 2006.

[5]. Fullerton, T., Swain, C., Hoffman. S. Game Design Workshop: Designing, Prototyping, and Play-testing Games. CMP Books, San Francisco, New York & Lawrence, 2004.

[6]. Zagal, J., Mateas, M., Fernandez-Vara C., Hochhalter, B., Lichi N. Towards an ontological language for game analysis. In: S. de Castell & J.Jenson(eds.), Changing views: Worlds in play: Selected papers of DIGRA 2005(pp.3-14), Vancouver, British Columbia, Canada: Digital Games Research Association. 2005

[7]. Lundgren, S., Björk S. Describing computer-augmented games in terms of interaction. Paper presented at Technologies for Interactive Digital Storytelling and Entertainment, Darmstadt, Germany, 2003.

[8]. Nakagawa, T.R.M., Minatoya, H. Information dynamics in judo. Research Journal of Budo, 47(1), 29-45, 2014.

[9]. Iida, H., Nakagawa, T., Spoerter, K. Game information dynamic models based on fluid mechanics. Entertainment and Computing, 3, 89-99, 2012.

[10]. Iida, H., Nakagawa, T., Nossal, N. Certainty of patient survival with reference to game information dynamic model. Open Journal of Preventive Medicine, 2(4), 490-498, 2012.

[11]. Nakagawa, T., Nakagawa, A. A safety lead curve and entertainment in games. International Review of Social Sciences and Humanities, 7(1), 91-103, 2014.

[12]. Nakagawa, T.R.M., Iida, H. Three game patterns. International Journal of Research Studies in Computer Sciences and Engineering, 1(1), 1-12, 2014.

[13]. Nakagawa, T., Iida, H., Morichika, H., Ohura, S., Yonenaga, K. Human and interaction in Shogi. Research Journal of Computation and Mathematics, 2(1), 7-13, 2014

[14]. Nakagawa, T., Nakagawa, A. Information dynamics analyses on American Foot Ball. Social Sci J. 6(1), 26-40, 2020.

[15]. Neumann, J., von Morgenstern, O. Theory of Games and Economics Behavior. Princeton University Press, 1944.

[16]. Blasius, H. Grenzschiten Flüssigkeiten mit kleiner Reibung. Inaugural- Dissertation zur Erlangung der Doktorwürde der Hohen Philosophischen Fakultät Georgia Augusta zur Göttingen, Druck von B.G. Teubner in Leipzig, 1907.

[17]. Prandtl L. Über Flüssigkeitsbewegung bei sehr kleiner Reibung. Verhandlungen des 3rd Internationalen Mathematiker-Kongresses, Heidelberg, Leipzig: Teubner, 1904

[18]. Schlichting H. Boundary-Layer Theory (translated by J. Kestin), McGraw-Hill, New York, 6th Edition, 1968

[19]. Solso, R. Cognition and the Visual Arts. MIT Press, Cambridge, 1994

Appendix 1 Game Pattern

Let us define game patterns, for we often encounter the typical patterns such as see-saw, balanced, and one-sided games in baseball, soccer, American football, boxing, chess, horse race, judo, or sumo. However, there has been no definition for game patterns, so that it may be worth proposing it for the promotion of understanding games. First of all, games are categorized as see-saw, balanced, one-sided and non-categorized, and it is proposed that these are defined, respectively, as follows,

a) See-saw game: Sign in advantage α alters over 3 times during the game andthe peak value of α at each the 3 periods must greater (smaller) than 0.05(- 0.05).
b) Balanced game: Absolute value of advantage|α|is always smaller than 0.05during the game: $|\alpha|<0.05$ for $0\leq \eta \leq 1$
c) One-sided game: Advantage α is equal or greater (smaller) than 0.05(-0.05)over the 90% of the total time.
d) Non-categorized game: All of the rest games other than the above three patterns.

Appendix 2 Information Dynamic Model

Currently, information dynamic model only makes it possible to treat and identify game progress patterns depending on the time. In this model, information of game outcome is expressed as a simple analytical function depending on the time, where information of game outcome is certainty of game outcome. In this Appendix, the information dynamic model has been introduced.

Modelling Procedure

The modeling procedures of information dynamics based on fluid mechanicsare summarized as follows:

a) Assume a flow problem as the information dynamic model and solve it.
b) Get the solutions, depending on the position (or time).
c) Examine whether any solution of the problem can correspond to gameinformation.
d) If so, visualize the assumed flow with some means. If not, return the firststep.
e) Determine the correspondence between the flow solution and gameinformation.
f) Obtain the mathematical expression of the information dynamic model.

The information dynamic model will be constructed by following the aboveprocedures step by step.

a) Let us assume flow past a flat plate at incident angle of zero as theinformation dynamic model (Figure 4).

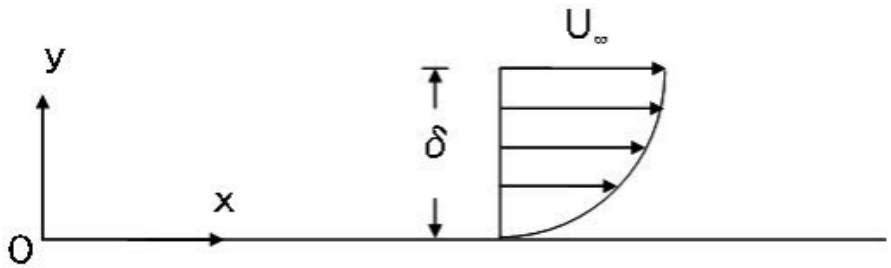


Figure 4 Definition sketch of flow past a flat plate at incident angle of zero.

An example of the application of the boundary-layer equations, which is the simplified version of Navier-Stokes equations [18], is afforded by the flow along a very thin flat plate at incident angle of zero. Historically this is the first example illustrating the application of Prandtl's boundary layer theory [17]; it hasbeen discussed by Blasius [16] in his doctoral thesis at Göttingen. Let the leading edge of the plate be at x=0, the plate being parallel to the x-axis and infinitely long downstream, as shown in Figure 4. We shall consider steady flow with a free-stream velocity U, which is parallel to the x-axis. The boundary-layer equations [17,18] are expressed by

$$u \cdot \partial u/\partial x + v \cdot \partial u/\partial y = -1/\rho \cdot dp/dx + \nu \partial^2 u/\partial y^2, \tag{5}$$

$$\partial u/\partial x + \partial v/\partial y = 0 \tag{6}$$

$$y = 0: u = v = 0; \qquad y = 1: u = U, v=0. \tag{7}$$

where u and v are velocity components in the x- and y- directions, respectively,ρ the density, p the pressure and ν the kinematic viscosity of the fluid. In the free stream by using the conditions at the outer edge of the boundary layer in (7), we obtain

$$U \cdot dU/dx = -1/\rho \cdot dp/dx. \tag{8}$$

The free-stream velocity U is constant in this case, so that dp/dx=0, and so dp/dy =0. Since the system under consideration has no preferred length, it is reasonable to suppose that the velocity profiles at varying distances from theleading edge are similar to each other, which means that the velocity curves u(y) for varying distances x can be made identical by selecting suitable scalefactors for u and y. The scale factors for u and y appear quite naturally as the free-stream velocity, U and the boundary-layer thickness, δ(x). Hence, the velocity profiles in the boundary-layer can be written as

$$u/U = f(y/\delta). \tag{9}$$

Blasius [15] has obtained the solution in the form of a series expansion aroundy/δ = 0 and an asymptotic expansion for y/δ being very large, and then the twoforms being matched at a suitable value of y/δ.

a) The similarity of velocity profile is here accounted for by assuming that function f depends on y/δ only, and contains no additional free parameter. Thefunction f must vanish at the wall (y = 0) and tend to the value of 1 at the outeredge of the boundary-layer (y = δ), in view of the boundary conditions for f(y/δ) = u/U.

When using the approximate method, it is expedient to place the point at which this transition occurs at a finite distance from the wall, or in other words, to assume a finite boundary-layer thickness δ(x) in spite of the fact that all exact solutions of boundary-layer equations tend asymptotically to the free-stream associated with the particular problem. The" approximate method" here means that all the procedures are to find approximate solutions to the exact solution. When writing down an approximate solution of the present flow, it is necessary to satisfy certain boundary condition for u(y). At least the no-slip condition u = oat y = 0 and the condition of the continuity when passing from the boundary- layer profile to the free-stream velocity, so that u = U at y = δ, must be satisfied.

The following velocity profile satisfies all of the boundary conditions as the tentative solutions (Ansatz L**ö**sungen in German**)** on the flow past a flat plate atincident angle of zero**,**

$$u/U = (y/\delta)^m, \quad (10)$$

where m is positive real number. Eq. (10) is solutions for the assumed flow.This is heuristically discovered, and represents a group of the approximate solutions with each different value of m. When m=1, (10) becomes the exact solution, but all of the rest solutions are approximate solutions to exact solutions, respectively.

a) Let us examine whether this solution is game information or not. Such an examination immediately provides us that the non-dimensional velocity varies from 0 to 1 with increasing the non-dimensional vertical distance y/δ in many ways as the non-dimensional information, so that these solutions can be gameinformation. However, validity of this conjecture shall be confirmed by the relevant data.
b) Imagine that the assumed flow is visualized with neutral buoyant particles. Motion of the visualized particles is detected by the eye almost instantaneously through the lights and is mapped on our retina first [19], so that during these processes, motion of" fluid particles" is transformed into that of the" information particles" by the light carrying the images of fluid particles. This is why motion ofthe fluid particles is intact in the physical space, but only the reflected lights, or electromagnetic waves consisting of photons can reach at the retina. The photons are then converted to electrochemical particles and are passed along the visual cortex for further processing in parts of the cerebral cortex [19]. The photons and/or electrochemical particles are considered to be information particles. It is, therefore, natural to expect that the flow in the physical space is faithfully transformed to that in the information space, or brain including eye. During this transformation, the flow solution in the physical space changes into the information solution in the information space.
c) Proposed are correspondences between the flow and game information,which are listed in Table 2.

Table 2: Correspondences between flow and game information

Flow	Game
u: flow velocity	I: current information
U: free stream velocity	I0: total information
y: vertical co-ordinate	t: current time
δ: boundary layer thickness	t0: total time

a) Considering the correspondences in Table 2**,** (10) can be rewritten as $I/I_0 = (t/t_0)^m$ (11)

Introducing the following normalized variables in (11)**,**

$\xi = I/I_0$ and $\eta = t/t_0$**,**

we finally obtain the analytical expression of the information dynamic model as

$$\xi = \eta^m, \quad (12)$$

where ξ is the normalized information**,** η the normalized time**,** and m is apositive real number.

Figure 4 shows the relation between certainty of game outcome ξ and normalized time η, where a total of 9 model curves have been plotted concurrently. This figure clearly suggests versatility of this model (12), for each of the curve represents a game. Thus, this model can represent any game in principle, where each of games takes a unique value of m. The smaller the strength difference between both teams (or players) is, the greater the value of m, and vice versa.

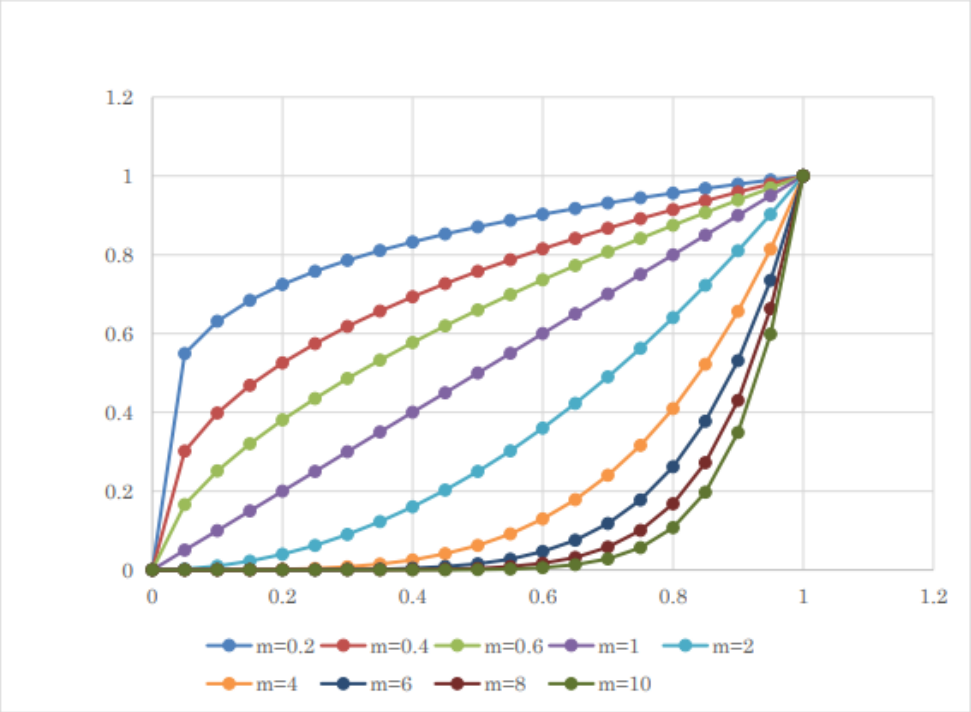


Figure 5 Certainty of game outcome ξ against normalized time η.

Global Research in Environment and Sustainability
December 2023, Vol. 1, No. 10, pp. 19-36.

Farming System Characterization in Selected Zones of SNNPR, Ethiopia

Tsadiku Alemu and Dekamo Fiseha

1. Hawassa Agricultural Research Center, SARI, Hawassa, Ethiopia

Abstract:
In Ethiopia, agriculture has a significant contribution to the GDP and export items of the country. Bearing this in mind, it is important to characterize the farming system to develop climate smart and demand-driven agricultural technology for farmers. Thus, this study was conducted to explore the changes in farming systems over time and identify the factors that contributed to the change across the different agro-ecologies with cross-sectional data of 160 sample respondents. The multi-stage sampling procedure was employed to select 160 sample households. The Major means of livelihood were crop cultivation (98.44%) followed by animal rearing (93.75%) in highland and crop accounts for 94.79% and animal rearing covers 91.67% in midland areas. The major identified farming systems were enset and barley-based mixed farming system, maize-based mixed farming system, coffee-based mixed farming system, agro-pastoral farming system, and chat and enset-based mixed farming systems. The major crops in the study area were maize, common bean, finger millet, teff, potato, coffee, barley, and enset. The major livestock resources were cattle, chickens, sheep, goats, and donkeys. According to the respondents, 48(30%) had physical soil and water conservation structures on their farmland. The farming system in the study area has shown dynamism due to driving factors related to climate change and variability, land use changes, an association of farmers, and government policies. Responses of the farming systems to existing agriculture-related policy directions include the introduction of mechanization and cluster farming. The major coping mechanisms to climate change include selling livestock, buying food, eating fewer meals in a day, and storing grain for the future. Major adaptation strategies include adjusting planting dates, changing crop varieties, decreasing livestock owned, and changing crop type. In crop production among other factors, low availability of improved seed takes the upper hand with market information delivery as the prior problem. In the livestock sector, disease occurrence in production and credit unavailability for trading were top problems. In natural resource management, soil fertility among others took the upper place as a problem. Therefore, improving access to improved varieties and breeds, raising farmers' awareness of the livestock disease and improved crop management practices, working to improve market information, market infrastructure, and pricing strategies, focusing on post-harvest management practices, expanding soil and water conservation, maintaining the already constructed structure and working in improving women's access to agricultural extension services by focusing on easily participative sub-sectors are recommended.

Keywords: Crop, Characterization, Farming, Livestock

INTRODUCTION

Background and Justification

Agriculture covers 45% of the total GDP, contributes 90% of the total export, and is the main foreign currency earnings source (CSA, 2018). A farming system is defined as "a population of

individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods, and constraints, and for which similar development strategies and interventions would be appropriate (Dixon et al., 2001). Pasquet (2007) also defined a farming system as "a group of intertwined activities and lines of production that a farmer and farm household conduct according to their objectives and needs, depending on changing environmental, economic, technical and cultural conditions and constraints". SNNPR is one of the largest regions in Ethiopia, accounting for more than 10 percent of the country's land area and one-fifth of the country's population. Of this amount, around 10% are estimated to live in urban areas and the rest 90% were residents in rural areas depending on crop production and livestock raising (Aynalem, 2014). The majority of farmers in the SNNPR of Ethiopia are smallholders, producing mostly for their consumption. They are estimated to generate 95% of total production for the main crops (cereals, pulses, oil seeds, vegetables, root crops, fruits, and cash crops). The average yield of the crops at all landscape positions was below optimum level due to the lack of site-specific soil fertility management, low soil fertility status, the decline in soil fertility, little fertilizer use, cultivation of steep slopes, lack of improved varieties, improper agronomic practices, lack of control of weeds, pests and diseases, rain shortage, and lack of suitable cultivars for different climatic conditions, post-harvest loss and other biological and physical factors (Alemu, et.al, 2016; Ahmed, 2017). The livestock production system is mainly extensive. Local breeds are predominant and are characterized by low milk production (Roberts and Carlo, 2014). No study was conducted to address the farming system of SNNPR in Ethiopia Therefore, to develop demand-driven agricultural technology and promote climate-smart agriculture and a market-oriented production system in the region, farming system characterization is detrimental. Moreover, this dynamism in the farming system: shifting to agroforestry system, vegetable, and root and tuber crop-based farming and change in income source, changing livelihood options, and lack of update information on farming and production system highly demands farming system characterization study. Hence, it is indispensable to undertake a farming system characterization study that is a detrimental factor for agricultural productivity maximization, adoption, and promotion of climate-smart and market-oriented production in the region.

METHODOLOGIES

Description of the Study Area

Arbegona Woreda: is one of the woredas in the Sidama Region. It is characterized by mountainous landscape having an altitude ranges from 2000 ma.s.l to 3336 m.a.s.l and 1500ma.s.l to 3700 ma.s.l respectively (Feleke et al., 2015). It exhibits a bimodal rainfall pattern. Arbegona woreda has a minor rainy season between February to April and major rainfall between July to October with annual rainfall which ranges between 1250 to1300 mm, and the temperature ranges between a minimum of 14°C and a maximum of 18°C (AWAO, 2007). The major livestock reared in the Arbegona district were cattle, sheep, goats, mules, beekeeping, donkeys, horses, and poultry (AWAO, 2007).

Halaba Zone: is found in Southern Nation Nationalities, and Peoples Region. The total area of the Woreda is 91,230 hectares of land, among that 70% flat, 27% slope and 3% mountainous. The Elevation ranges of the Woreda from 1554-2149 m.a.s.l, the mean annual Rain falls of the area ranges from 857-1085 mm, and the mean annual average temperature ranges from 17 – 20 degrees centigrade. The climatic condition of the area is 97% dry intermediate high land and 3% moist intermediate high land. The rainfall pattern is erratic and irregular in the area. Due to the severe and heavy rains, soil erosion and flooding are very common in the study area (Mesay, 2012).

Boricha Woreda: is in Sidama region. It has 588.05 sq.km² areas. Woreda is agro-ecologically categorized into two: 25% is midland (*Woynadega*) and 75% is lowland (*Kola*). *Woynadega* has medium altitude, whereas *kola* has low altitude. The altitude of woreda ranges from 1,320 to 2,080 m.a.s.l. The range of annual rainfall is between 27.82 to 128.58mm. It is bimodal with the short rainy season from March to April which is '*Belg'*, and the long rainy season from June to the middle of August which is '*Kiremt*'. The range of annual temperature of the woreda is between 21.93°c to 25.56°c. The economy of the woreda is mainly based on agriculture. A mixed farming system is a dominant activity for rural households. It is confined to the production of rain-fed crops. The main crops produced in the study area are maize, haricot bean, *Enset,* coffee, potato, and sweet potato (Yoseph et al., 2012).

Dilla Zuria Woreda: Topographically, the area revealed undulated plateau at the upper limit to the valley and a plain in the lower limit. Its altitude ranges between 1750-2200 m above sea level and covers about 75,000 km². The average annual rainfall and temperature are 1300 mm and 21°C respectively. The area has two major rainy seasons (spring and summer) (Tesfahun and Temesgen, 2014).

Gedeb Woreda: Its altitude ranges from 1950 m up to 2650 m; the annual rainfall ranges from 1290 -1800 mm the temperature ranges from 16-21. The land-use system of the *wereda* is mostly a mixed farming system. Most of the land was cultivated by annual crops of 12,756 hectares, perennial crops of 16,372 hectares, and pasture land coverage of 244 hectares. The potential for cultivable land is 402 hectares; the area covered by forest and shrubs is 386 hectares, uncultivable land is 83 hectares, and 457 hectares are occupied by other uses (AGP, 2010).

Sampling Techniques

A multi-stage sampling procedure was employed to select representative sample respondents. In the first stage, Arbegona, Boricha, and Atoti Ulo *woredas* were selected purposively depending on their representativeness in the existing socio-economic, socio-cultural, and agro-ecological diversities of the targeted population of the zone. In the second stage, the kebeles were stratified based on farmers' farming system clusters to capture the existing socio-economic, socio-cultural, and agro-ecological diversities of the targeted population. In the third stage, nine *kebeles* (four from highland and five from midland) were selected purposively from the farming system cluster with the consultation of experts from each district based on the existing socio-economic, socio-cultural, and agro-ecological diversities of the targeted population of each *woreda*. Finally, 160 sample respondents were selected randomly from strata based on proportional probability size.

Method of Data Analysis

Qualitative data collected during focused group discussion and key informants' interviews were presented in narration. Quantitative data were analyzed using STATA software and the results are presented in descriptive statistics such as minimum, maximum, mean, standard deviation, frequency, and percentage based on the type of data.

RESULTS AND DISCUSSION

Demographic and Socio-Economic Characteristics of Respondents

As presented in Table 1, the average age (t=-2.58) and education levels (t=2.85) of the sampled households in terms of comparison between highland and midland showed a statistically significant mean difference. Midland farmers are more aged than that of highland areas which might increase experience in years of engagement in farming activities. Among the total sample

respondents, about 93.12% were males and 6.88% were female household heads. Concerning marital status, 88.74% were married, 8.13% were single and 3.13% were widowed. Crops cultivation remains to be a dominant economic activity and source of livelihood in the two agro-ecologies with 98.44% and 94.79% of respondents have participated in highland and midland agro-ecologies respectively. Animal rearing, beekeeping, nonfarm and off-farm activities take the next consecutive shares (in the case of highland agroecology 93.75%, 15.63%, 14.06%, and 7.81%, and midland they account for 94.79%, 91.67%, 28.13%, 9.38%, and 7.29% respectively). There is a statistically significant difference between highland and midland in terms of the percentage contribution of animal rearing and beekeeping as a means of livelihood earning activities.

Table 1: Summary of demographic and socio – economic characteristics of respondents

Variables		**Midland n = 96**	**Highland n = 64**	**Overall n = 160**	**χ^2/t- test**
Age (years)		41.95	37.17	40.04	2.58**
Education status		4.66	6.45	5.375	-2.85**
Family size		7.55	7.9	7.69	-0.52
Sex (male)		86 (89.58)	63 (98.44)	149 (93.12)	4.70**
Marital status	Married	81 (84.34)	61 (95.31)	142 (88.74)	5.40*
	Single	10 (10.42)	3 (4.69)	13 (8.13)	
	Widowed	5 (3.13)		5 (3.13)	
Crop cultivation HHs (yes)		94.79%	98.44%		1.40
Animal rearing HHs (yes)		91.67%	93.75%		3.32*
Off – farm activity HHs (yes)		7.29%	7.81%		0.01
Non – farm activity HHs (yes)		9.38%	14.06%		0.85
Beekeeping activities (yes)		28.13%	15.63%		3.28*

Source: Survey result, 2021

Land Ownership

Land tenure and how the land under the farmers' control was utilized were observed in the study. The result in Table 2 shows that there is a statistically significant mean difference between highland and midland agro-ecologies in terms of average lands allotted to grazing (t=2.32) and multipurpose tree plantation purposes (t=4.54). This implies on average higher hectares of land allotted to grazing and multipurpose trees in highland areas.

Table 2: Summary of land tenure

Variables	**Highland n = 64**				**Midland n = 96**				**t – test**
	Mean	Min	Max	S. D	Mean	Min	Max	S. D	
Total Land	1.41	0.27	3.59	0.81	1.52	0.27	3.47	0.83	-0.82
Annual crop land	0.69	0.02	2.5	0.50	0.98	0.02	2.5	0.84	-1.38
Perennial crop land	0.35	0.03	0.75	0.20	0.25	0.03	0.75	0.24	1.49
Grazing land	0.15	0.11	0.23	0.06	0.13	0.11	0.23	0.04	2.32**
Multipurpose trees	0.11	0.01	0.25	0.10	0.05	0.01	0.25	0.02	4.54***

Source: Survey result, 2021

Types of Farming Systems in the Study Areas

As per the survey results and using (USAID, 2005), the following five types of farming systems were identified in the study area to help development practitioners get acquainted with the potential areas of agricultural production system:

Enset and Barley-Based Mixed Farming System:

Sidama-Gedeo highland enset and barley potential growing areas are included in this type of farming system. This group includes the Arbegona, Hulla, Bensa, Aroresa, frm Sidama, and Bule, and Kochere from Gedeo. With slope percentages ranging from 5 to 20 percent, the topography is hilly. The year-round low temperatures are a result of the area's altitude, which ranges from 2100 to 3200 meters above sea level. Very little vegetation is present, and the predominant soil type is a brown clay loam. With about 350 persons per square kilometer, the population density is average when compared to the nearby midland coffee-producing areas. Mixed farming is common. The primary food crops are enset, barley, wheat, horse beans, peas, and maize, in decreasing order of importance. The three main income crops in this classification are garlic, cabbage, and shallots (known locally as kitel *shinkurt*). Although some farmers use animal traction, the majority cultivate by hand. Cattle, sheep, and horses are the three principal categories of livestock raised. The majority of farmers have their own grazing land and typically raise more animals than other farming systems. This is due in part to larger land holdings, places that can only be used for grazing due to flooding, and relatively abundant pasture throughout most of the year due to rainfall. There is a seasonal movement of livestock to the valleys surrounding the Arsi and Bale administrative zones of the Oromiya Region during May and June, the two months when grass and crop residues are less readily available locally. Due to the lack of all-weather roads, this farming system areas have low market accessibility from the highland region of Arbegona woreda. In this area, doing local casual employment is viewed as shameful. Poor households avoid working locally as a result, moving elsewhere during harvest to adjacent coffee-growing regions. During times of peak production, better-off households engage communal labor to cultivate their fields while feeding and giving drinks to the workers.

Maize-Based Farming System:

It covers the lowest areas of the Sidama region like portions of Hawassa, Dale, Aleto Wondo, Dara, Bensa, and Aroresa woredas, Boricha woreda, parts of Gedeo zone, such as Dillazuria woreda, and the majority of Halaba zone. Although many officials refer to it as lowland or kolla, it actually lies on the border of the kola and woinadega agro-ecological zones, with elevations between 1400 and 1700 meters above sea level. The belg and kremt rains, which occur twice a year, bring about an average rainfall of 700 to 1200 millimeters. Plains and undulating hills make up the landscape. The population heavily relies on artificial ponds and shallow wells for water for both people and cattle because there aren't many rivers that traverse this farming system.

These have a tendency to dry out between December and February, which poses a serious issue for the availability of water. The major crop, maize, is only planted once a year, therefore farmers identify themselves as being belg-dependent due to the importance of the belg rains in March and April for crop production. Irish potatoes, sweet potatoes, and other food crops like haricot beans can be planted twice a year, during each rainy season. Farmers intensify the area planted with these quickly growing crops during the ensuing meher season to make up for the lost corn when the belg rains are insufficient and maize production fails. In the majority of this Sidama agricultural system area, enset is planted as a perennial food crop. But compared to the close-by midland and highland parts of Sidama, it is less significant here. This farming system consists of coffee, chat, and hot peppers. Both hand cultivation and, for some wealthier households, oxen-pulled plows are methods of land preparation. The principal animals raised in the Sidama Maize Belt are cattle, goats, and donkeys. Since pasture and browse are easier to acquire by in the lower, more remote places, it is common to keep cattle and goats there. Donkeys are necessary for the transportation of firewood, water, and goods for trade.

Coffee Based Farming System:
It covers the midland (*woinadega*) areas of the Sidama region parts of Dara, AletoWondo, Dale, Shebedino, Awassa, Hulla, Bensa, and Aroresa woredas. In addition, it includes Yirgachefe areas of the Gedeo zone. Altitudes range from 1700–2300 meters above sea level. The landscape is characterized by undulating hills and, due to the high population density, most of the land is cultivated. This is a visibly green part of with, with eucalyptus, fruit, and coffee trees prominent and enset stems growing around every house. However, there is no natural forest and very limited communal grazing land. Rainfall in this farming system is more reliable than in the neighboring maize belt and falls during two rainy seasons, the *belg* and *kremt* rains.

Coffee is the main cash crop and enset is the main food crop, and these are supplemented by small quantities of other rainfed food crops (including maize, haricot beans, and sweet potatoes) and fruits (including avocado and pineapple). Annual food crops are generally intercropped amongst the coffee and enset plants. As a result, plow oxen are rarely used for cultivation in this farming zone; most cultivation is done by hand. Due to small landholding sizes and the large proportion of land that is dedicated to coffee production, most households do not produce enough food crops to last throughout the year, even in a year of good crop production. Market reliance is therefore quite high in this farming system, suggesting that both cash crop and staple food prices should be closely monitored.

Agro-Pastoral Farming System:
It covers the western lowlands of Boricha and Dale woredas in the Sidama region. The southern part of this farming system area borders the Oromia region. The topography of the zone is mainly flat, with a gentle decline from east to west, where the large perennial Bilate River provides a boundary. The altitude range is from 560-1700 meters above sea level. Lower areas of the livelihood zone are covered with relatively dense bush, while higher altitude areas have less vegetation cover. Farmers plant along the river and use the area between high cliffs to the east and the river to the west for grazing in a communal grazing area with lots of bush and grass. The soil type is mainly sandy loam of grey color and, because it is susceptible to erosion, gullies and gorges cross the zone. The zone is full of termite hills, which affects the availability of cultivable and grazing land. This is a low rainfall area with a sporadic rainfall pattern during the two rainy seasons. The *belg* rains fall from February to April and the *kremt* rains from July to early October. Temperatures are relatively hot, ranging from 26oc -33oc. Households live together and share resources in common. They have significant livestock numbers per household, and livestock and livestock product sales are the main cash income sources. The types of livestock reared in the zone are cattle, goats, sheep, and donkeys (in descending order of importance). There is a large amount of communal grazing land in the Bilate Valley, which attracts additional livestock from the neighboring Sidama Maize Belt. There is no outmigration of livestock. The main staple food crops in the zone are maize, haricot beans, *enset*, and sweet potato, all produced in relatively small amounts. Chat is an income-generating crop in the higher-altitude areas of this farming system, but it is not typical as a whole. Farmers use animal traction to plow their land and they have both rainfed and irrigated land. Excessive rains are beneficial in one sense, allowing pasture to flourish, and detrimental in another sense, flooding irrigated crops. The opposite is true in drought years: livestock, pasture, and rainfed crops suffer, while irrigated crops thrive. On balance, agro-pastoralists in this livelihood zone prefer to have heavy rains, reflecting the importance of livestock over crops.

Chat and Enset-Based Farming System:

This system of farming includes Wondogenet woreda of the Sidama region. It has a bimodal rainfall pattern, with the *belg* rains falling from February – April and the *kremt* rains falling from June – October. Temperatures range from 16°c – 28°c. Mixed farming is the main agricultural system in this farming system. Chat, sugarcane, avocado, mango, and vegetables like head cabbage are the main cash crops. Enset, maize, haricot beans, and Irish potatoes are the main food crops.

Crop Production in the Farming System:

Major Crops and Productivity:

In both highland and midland areas, the farmers are practicing mixed farming at the subsistence level. Crop cultivation in the study areas mainly depends on the rain-fed system. Major crops grown by farmers in the study areas were summarized in Table 3. Maize, common bean, finger millet, potato, coffee, barley, and enset were the most important crops in the highland and midland agro-ecologies while barley was grown only in highland agroecology. Finger millet and teff were confined to midland areas in production. In addition to these major crops on the side of midland crop items, the Arbegona district of the Sidama region and Gedeb district from the Gedeo Zone are well known for growing vegetables (head cabbage primarily) which are worth attention. From a highland agro-ecological setting, the Dilla Zuria district is endowed with the potential to grow fruits like avocado, mango, and banana in addition to those as crops of midland areas. Boricha district of Sidama region requires the focus of intervention in research and development of vegetable production like head cabbage and sugarcane. There is a statistically significant mean difference in yield per hectare of maize, common bean, and potato crops between the two agro-ecological settings.

Table 3: Summary of major crops and their productivity

Major crops	**Highland (n =64)**				**Midland (n =96)**				**Yield/ha t - test**
	%HHs grown	Area (Ha)	**Total prdn**	**Yield (Qt/ha)**	%HHs grown	Area (Ha)	**Total prodn**	**Yield (Qt/ha)**	
Maize	21.88	0.37	148	37.35	70.83	0.67	1052	30.74	1.99*
Common bean	4.69	0.55	21	12.5	38.54	0.34	171	13.5	-8.38***
Finger millet	-	-	-	-	37.5	0.47	198	11.8	-
Teff	-	-	-	-	16.67	0.21	45	13.4	-
Potato	7.81	0.27	22	20.11	28.13	0.58	896	61.85	-2.33**
Coffee	10.94	0.10	9.07	13.79	28.13	0.15	44.85	11.53	1.16
Barley	62.5	0.85	602	17.8	-	-	-	-	
Enset	70.31	0.39	-	-	23.96	0.35	-	-	

Source: Survey result, 2021

Improved Variety and Agronomy Use Practices:

As shown in Table 4 below, the use of improved variety and row planting practices are shown as the percentage of total producers of each major crop. In highland areas, the use of improved varieties for maize, common bean, potato, coffee, and barley accounts for 85.71%, 66.67%,60.00 %, 28.57%, and 72.50% respectively. Row planting agronomic practices in highland for maize, common bean, potato, coffee, barley and enset accounts for 78.57%, 33.33%, 80.00%, 42.86%,85% and 20.00% respectively. Varieties being used for maize in highland areas include

BH-661. The dominant variety of barley is Eboni. The common bean variety includes Hawassa Dume. In midland areas, the use of improved varieties for maize, common bean, finger millet, teff, potato, coffee, and barley accounts for 88.24%, 81.08%,19.44%, 43.75%, 81.48%, and 22.22% respectively. Row planting agronomic practices in midland for maize, common bean, finger millet, teff, potato, coffee, and enset accounts for 76.47%,72.97 %,25.00%, 37.50%, 74.07%,29.63%, and 21.74% respectively. In the case of midland agroecology, maize varieties include Limu, Shone, and Damot. The potato varieties are Tadesse and NechAbeba. The dominant common bean varieties are HawassaDume and to some extent Nasir. The improved variety of Teff typical to the study area is Cross-37.

Table 4: The use of improved varieties and row planting

Crop	Highland (n =64)	Midland (n =96)	χ^2/t- test
Maize improved varieties users	85.71	88.24	0.08
Maize row planting	78.57	76.47	0.09
Common bean improved varieties users	66.67	81.08	4.12**
Common bean row planting	33.33	72.97	22.02***
Finger millet improved varieties	-	19.44	
Finger millet row planting		25	
Teff improved variety users	-	43.75	
Teff row planting		37.5	
Potato improved variety users	60.00	81.48	9.22***
Potato row planting	80	74.07	0.006
Coffee improved variety users	28.57	22.22	0.81
Coffee row planting	42.86	29.63	2.89*
Barley improved variety users	72.50	-	
Barley row planting	85		
Enset improved varieties	-	-	
Enset row planting	20	21.74	0.02

Source: Survey result, 2021

Grain Storage Practices in the Study Areas:

Grains are stored in locally made structures using woods and byproducts of crops like maize. These structures make the stored crops vulnerable to attacks by weevils, rodents, and fungal attacks because the nature of the surface area of locally made structures is not safe enough to prevent rodents, and no remedies to contain the effect of excessive heat. Farmers try to control storage-related problems by using a combination of techniques like applying ashes, Smoking, and spraying chemicals.

Agricultural Mechanization in the Study Areas:

The use of mechanization is confined to areas of agricultural commercialization clusters that have been established in collaboration with the Agricultural Transformation Agency (ATA) in areas like the Halaba zone.

According to the survey result, the use of animal draft power is 36.25%. The percent of mechanization in terms of the use of a tractor is 8.13%. These respondents were from Atoti Ulo woreda, Halaba zone. There were no respondents who reported having used combiners for harvesting crops.

Major Constraints in Crop Production:

According to the response of farmers and experts, low availability of improved seeds, the high price of agricultural inputs, delay of inputs, variability of crop varieties coming into the hands of farmers, erratic nature of rainfall, inadequate market infrastructure, lack of market information, lack of processing units, lack of modern storage facilities and price fluctuation were major constraints in production and marketing aspects of crops (Table 5).

Table 5: Crop production and marketing constraints

Production constraint	Rank	Marketing constraint	Rank
Low availability of improved/hybrid seed	1	Inadequate market infrastructure	1
The high price of agricultural inputs	2	Lack of market information system	2
Delay of the inputs at the required time	3	Lack of processing units	3
Variability in the type of crop varieties coming into the hands of farmers	4	Lack of modern storage facility	4
Erratic nature of rainfall	5	Price fluctuation	5
Shortage of farm implements and labor	6		

Source: Survey result, 2021

Livestock Production in the Farming System:

Livestock Ownership:

Livestock ownership statistics of sampled households are summarized in Table 6, with the percent of respondents owning the livestock types and average TLU. About 10.94% had oxen herd size of 1.83 TLU in highland and 39.58% with 2.00 TLU herd sizes oxen in midland. Of total respondents, 50.00% were with 3.48 TLU cow herd size and 41.67% with 2.05 TLU cow herd size in highland and midland respectively.10.94% of respondents were with 2.00 TLU bull herd size and 11.46% were with 1.18 TLU herd sizes of a bull in highland and midland respectively. In terms of a heifer, 28.13% with 1.76 TLU and 4.17% with 1.31 TLU heard the size of heifers is owned highland and midland respectively. The population of calves was 26.44% with 0.48 TLU and 12.50% with 0.43 TLU in highland and midland agro-ecologies respectively. Chicken population ownership is 26.69% with 0.03 TLU and 42.71% with 0.07 TLU in highland and midland respectively. Sheep ownership is 25.00% with 0.54 TLU and 20.83% with 0.49 TLU in highland and midland respectively. Goats are exclusive to midland agroecology with 26.04% and 0.41 TLU. Donkeys account for 14.58% with 1.00 TLU. There is a statistically significant mean difference between highland and midland in terms of Cow, bull, and chicken TLU.

Table 6: Household livestock ownership, the proportion of owners, and herd sizes (TLU)

Types of livestock	Highland(n=64)		Midland(n=96)		t- test
	%HHs	Mean TLU (std)	%HHs	Mean TLU (std)	
Oxen	10.94	1.83(1.33)	39.58	2.00(0.81)	-0.4291
Cow	50.00	3.48(2.12)	41.67	2.05(1.06)	3.65***
Bull	10.94	2.00(1.00)	11.46	1.18(0.40)	2.45**
Heifer	28.13	1.76(1.12)	4.17	1.31(1.13)	0.72
Calves	26.44	0.48(0.17)	12.50	0.43(0.21)	0.69
Chicken	29.69	0.03(0.01)	42.71	0.07(0.04)	-4.31***
Sheep	25.00	0.54(0.38)	20.83	0.49(0.36)	0.46
Goat	-	-	26.04	0.41(0.28)	-
Donkey	-	-	14.58	1.00(0.45)	-

Source: Survey result, 2021

Animal Feed Technologies:

As indicated in Table 7, the major sources of feeds for livestock in the study area were cut and carry system (55%), use of improved forage (48.75%), crop residues (46.25%), and concentrates of different feed types (21.87%) in their order of importance. The major types of available improved forages in the study area were desho grass (31.25%) and elephant grass (16.25%) as significant contributors to the livestock feeding for farmers.

Table 7: Sources and types of livestock feeds

Sources of feed	n = 160	%HH	Types of improved feed	n = 78	%HH
Cut & carry system	88	55.00	Urea treated straw	-	-
Hay making	27	16.88	Desho grass	50	64.11
Crop residues	74	46.25	Elephant grass	26	33.33
Concentrates of different types	35	21.87	Tree Lucerne	-	-
Improved forages	78	48.75	Susbania	-	-
Local beverage products	7	4.38	Oat-vetch	-	-
			Multi-nutrient block	2	2.56

Source: Survey result, 2021

Practices of Breeding Cows:

Different breeding practices used by the respondent for cows are shown below in Table 8. The major ones were uncontrolled bull service, AI/natural heating, controlled improved bull service, AI/ synchronization, and Improved bull service/uncontrolled in their order of importance with 75%, 8.13%, 6.88%, and 5% (both AI/synchronization and Improved bull service/uncontrolled) respectively.

Table 8: Summary of cow breeding practices

Types of breeding practices (N=160)	N	%HHs
AI /natural heating	13	8.13
AI/synchronization	8	5.00
Improved bull service/controlled	11	6.88
Improved bull service/uncontrolled	8	5.00
Local bull service/uncontrolled	120	75.00

Source: Survey result, 2021

Beekeeping Practice:

Beekeeping is a common practice in rural livelihoods as an income generation source and home consumption. As presented in Table 9, beekeeping practices and production of honey. The result shows that a few percent of the respondents in the survey areas own beehives in general (23.75%). Traditional, transitional and modern beehives were owned by 16.25%, 6.25%, and 7.5% of the respondents respectively.

Table 9: Summary of beekeeping practice

Beehives	n = 86	%HHs	Honey harvest Mean (SD)
Own beehives	38	23.75	-
Traditional beehives	26	16.25	23.04(17.61)
Transitional bee hives	10	6.25	13.25(10.00)
Modern bee hives	12	7.5	55.00 (28.87)

Source: Survey result, 2021

Livestock Production and Marketing Constraints:

Table 10 below indicated that disease, lack of improved breeds, inadequate accessibility of veterinary service, lack of credit, no nearby market, and absence of market information were major production and marketing constraints that impair the performance of the livestock sub-sector.

Table 10: Summary of livestock production and marketing constraints

Production constraint	Rank	Marketing constraint	Rank
Prevalence of livestock diseases	1	Inadequate availability of credit	1
Biological limitation of indigenous breeds	2	Poor access to organized markets	2
Shortage of feed	3	Absence of market information	3
Inadequate accessibility of veterinary service	4	Unregulated trading	4
Deficiency of vaccine and vaccine set-up	5		
Limited availability of quality breeding purpose bulls.	6		

Source: Survey result, 2021

Crop and Livestock Diseases in the Study Areas:

Milly bugs, rodents, aphids, white scale, and rust were major crop diseases and pests reported by the sampled respondents in the study area. Trypanosomiasis, blackleg, liver disease, anthrax, gororsa, CBPP, trypanosomiasis, pasteurellosis, coughing, and mastitis were the main livestock diseases, pests, and parasites are indicated in the table below Table 11.

Table 11: Summary of crop and livestock diseases in the study area

Crop disease/pests	Crop type affected	Prevalence area
Milly bug, rodents	Enset	Gedeb
Aphid	Head cabbage	Gedeb
White scale	Mango	Dillazuria
Rust	Wheat	Gedeb
Livestock disease/parasites	**Livestock type affected**	**Prevalence area**
Gendi(triphanosomiasis), Aba gorba (blackleg), Liver disease (Yegubetbeshita)	Cattle	Gedeb
Aba senga(antrax)	Cattle, sheep and equines	Gedeb, AtotiUlo
Ovinepastoralisis (Gororsa)	Cattle and sheep	Gedeb
Contagiousbovinepleuropneumonia (CBPP)	Cattle, goat, sheep	Dillazuria
Trypanosomiasis	Cattle	Dillazuria, Atoti
Pasteuorolosis	Goat and sheep	AtotiUlo
Blackleg	Cattle, goat, sheep	Dillazuria
Coughing	Sheep, poultry, and equines	Gedeb
Mastitis	Cattle	Arbegona

Source: Survey result, 2021

Natural Resource Management Practices in the Farming System:

Physical Soil and Water Conservation Structures:

According to the respondents, 48(30%) had physical soil and water conservation structures on their farmland while the issue of repairing the already constructed structures was given little attention at a time of mobilizing farmers for mass physical and biological soil and water conservation activities movement at a local level.

Types of Physical Soil and Water Conservation Structures:
Major types of physical soil and water conservation structures available in the study area were soil bund, terracing, fanyajuu, and gully stabilizer with 39.58%,37.50%,20.83%, and 2.08% proportion of households having them on farmland respectively (Table 12).

The results imply that due to variation in slopes, in highland areas terraces and soil bunds are dominant, whereas in midland areas soil bund takes the upper hand.

Table 12: Types of physical SWC structures

Types of SWC structures (N=48)	Highland		Midland		Total		χ^2
	N	%HHs	N	%HHs	N	%HHs	20.45***
Terracing	13	76.47	5	16.13	18	37.50	
Soil bund	2	11.76	17	54.84	19	39.58	
Fanyaju	1	5.88	9	29.03	10	20.84	
Stone bund	-	-	-	-	-	-	
Gully stabilizer	1	5.88	-	-	1	2.08	

Source: Survey result, 2021

Forestry and Agroforestry:
Gedeo zone is widely renowned for its agroforestry in comparison to other research areas. The area's upper story is primarily made up of native tree species such as Ficus spp., Cordia africana, Croton macrostachyus, and Millettia ferruginea, as well as fruit trees like mango (*Mangifera indica*) and avocado (*Persea americana*). The middle story is made up of dominant species like enset (Ensete ventricosum), a huge non-woody evergreen perennial herb, and coffee (*Coffea arabica L.),* an evergreen shrub. Vegetables, spices, and herbs frequently occupy the lower story. While enset is present at all elevations, the coffee component declines with elevation.

The Arbegona Garemba forest woodland in the Sidama region is renowned for its abundant flora. The vegetation of Arbegona Garemba woodland is comprised of alpine bamboo and damp evergreen Afromontane Forest. There are scattered ruminant trees in the area, including *Hagenia abyssinica, Juniperus procera, Olea Africana, Hypericum revoltum, and Erica arborea*, indicating that these species once dominated the middle and lower portions of the area's vegetative cover.

Among the faunal species are the Fan-tailed raven (*Streptopelia lugens*), Thick-billed raven (*Galerida theklae*), Alpine chat (*Cercomela sordida*), Mountain thrush (*Turdusoli vaceus*), Rupels robin chat (*Cossyphase mirufa*), Wattled ibis (*Cinnyris venustus*), Alpine swift (*Tachymarptis melba*), Dusky turtle dove (*Tockusalboter minatus*) and Red-winged starling (*Buphagusery throrhyncus*) are some of the avifauna species found in Arbegona Garemba forest. In Halaba dominant species include *Acacia albida, Sesbania,* and *Leucaena* which are found sparsely.

Major Constraints of Natural Resource Management:
Natural resource management practices are being undertaken in the study areas largely by community-based mobilization and to some extent the help of non-governmental agencies. However, the efforts are constrained by the challenges indicated below in Table 13. The use of inorganic fertilizers is not sufficient unless technologies like vermincompost are introduced to farmers.

Table 13: NRM production and marketing constraints.

Constraints	Rank
Declining soil fertility	1
Soil erosion and loss of topsoil, drought,	2
Land shortage	3
deforestation	4
soil acidity	5
lack of adequate knowledge of NRM management practices	6

Source: Survey result, 2021

Institutional Setting in the Study Areas:

Access to Credit for Agricultural Activities:

It is a fact that credit is the most important in technology adoption in terms of input purchase. Those who had access to credit/utilized credit services were 47(29.38%) of the total respondents. As indicated in Table 14, the purpose of taking credit was livestock production, crop production, trade, social issues, and purchase of food with 44.68%, 31.91%,8.51%,8.51%, and 6.38% respectively. The overall result indicates that much of the need inclines for purchase of livestock assets and crop production.

Table 14: Purposes of utilizing credit services

Purposes (N=47)	Highland		Midland		Total		χ^2
	N	%HHs	N	%HHs	N	%HHs	16.92***
Livestock production	6	23.08	15	71.43	21	44.69	
Crop production	12	46.15	3	14.29	15	31.91	
Trade	4	15.38	-	-	4	8.51	
Social issues/health, wedding	1	3.85	3	14.29	4	8.51	
Purchase of food	3	11.54	-	-	3	6.38	

Source: Survey result, 2021

Sources of Credit for Agricultural Activity:

The major sources of credit for agricultural activities are the respondents were microfinance institutions, friends/relatives/neighbors, and informal saving and credit institutions like "ikub" with 51.06%, 42.55%, and 6.39% respectively (Table 15). This implies that farmers are mostly reliant on friends' relatives and neighbors for loan in case microfinance services are not available.

Table 15: Summary of sources of credit for agricultural activities

Responses (N=47)	N	%HHs
Microfinance	24	51.06
Informal saving and credit institutions	3	6.39
Friends, relatives, neighbors	20	42.55
Banks	-	-
From coops/unions	-	-

Source: Survey result, 2021

Access to Extension Services:

As indicated in Table 16, in terms of agricultural extension services, those who had accessed/gotten extensions on improved crop management practices, livestock production, and natural resource management practices were 76.88%, 54.38%, and 61.25% respectively. This

result implies that extension services are more focused on crop production than natural resource management and livestock production that should have been important as well.

Table 16: Summary of extension services

Types of extension services (N=160)	N	%HHs
Extension of improved crop management	123	76.88
Extension of improved livestock production	87	54.38
Extension of improved NRM practices	98	61.25

Source: Survey result, 2021.

Climate Change/ Variability Related Problems:

It is a fact that climate change/variability affected farmers' livelihood. Many associated problems can be mentioned, the major ones encountered by the respondents were drought, too much rain, delay of belg season, high temperature, severe frost, heavy flood, outbreak grasshopper, outbreak pests, and diseases (Table 17).

Table 17: Summary of consequences of climate change/variability

Types of disaster (n =160)	N	%HHs
Drought or lack of rainfall	48	30.00
Too much rain	80	50.00
Erratic rainfall	69	43.13
Delay of belg season	43	26.88
High temperature	28	17.50
Severe frost	28	17.50
Heavy Flood	19	11.88
Outbreak of grasshopper	112	70.00
Outbreak of armyworm (temch)	58	36.25
The outbreak of other pests	25	15.63
Outbreak of disease/livestock	46	28.75
The proliferation of invasive weeds	9	5.63

Source: Survey result, 2021

Potential Drivers of Change in the Farming System:

The farming system has changed in the study area. These changes are derived by the potential factors like the use of improved varieties to increase production and productivity as the local variety which had been on the farmers hand could not withstand diseases as a result of climate change/variability, increasing crop mix over time in fear of risk related to loss of harvest from single crop item, decrease of livestock resource over time, shift from livestock to crop production to sustain food security as the land is fragmented due to population pressure and due to increasing prices of food items, disappearance of older varieties and substitution by the new ones, increased influence of crop and livestock diseases due to stress of heat and other factors, decline of land ownership, establishment of farmers based associations or cooperatives, expansion of towns as with the case of urban agriculture, introduction of cluster farming by the government to encourage agricultural commercialization and establishment of agro-processing industries. These issues in combination with government policies changed the way farmers used to produce crops and rear livestock (Source: KII and FGD).

Coping and Adaptation Strategies Being Followed by the Farmers

Coping and adaptation strategies of farmers as a response to climate change and variability are indicated below in Table 18. The top four coping mechanisms were buying food when the stored crop item runs out, selling livestock as the livestock resources are major assets to convert to cash in need of money for the purchase of input and other social-related issues, eating fewer meals per day to accommodate the amount for every member of the household and storing the grain for future with 55.00%, 53.13%, 48.75 and 43.13% respectively. The top four adaptation strategies being followed by the farmers were adjusting planting date in case of rain delay, changing crop varieties, decreasing the number of livestock, and planting grasses with 59.38%, 55.00%, 54.38%, and 50.00% respectively.

Table 18: Coping and adaptation strategies of respondents

Coping mechanism(N=160)	N	%HHs	adaptation strategies	N	%
Sold livestock	85	53.13	Change crop type	86	53.75
Rent out/ share out land	47	29.38	Change crop varieties	88	55.00
Borrowed money from friends or relatives	20	12.50	Change animal breeds	77	48.13
Borrowed money from OMO, coops, banks	24	15.00	Adjust planting date	95	59.38
Credit from traders and private money	20	12.50	Decrease livestock owned	87	54.38
Received food aid	10	6.25	Engage in beekeeping	38	23.75
Bought food	88	55.00	Plant trees	57	35.63
Ate less amount/ less meals per day	78	48.75	Planting grasses	80	50.00
Sought off-farm employment	42	26.25	Increase cultivable land	70	43.75
Grain storage/save grain for future	69	43.13	Engage in off -farm activity	42	26.25
Migrate to towns temporarily	-	-	Engage on irrigation	45	28.13
Send children for a housemaid	11	6.88	Water harvesting	40	25.00
Early marriage for girls	11	6.88	Got remittance	32	20.00
Give children for adoption	10	6.25	Take credit for inputs & improved farming	15	9.38
			Diversifying animal herds and selecting hardier breeds	40	25.00

Source: Survey result, 2021

Responses of the Farming Systems to Existing Agriculture-Related Policy Directions

The farmers in Atoti Ulo woreda started to work on a cluster farming system for maize which is the clear effect of government policy on the way farmers used to produce crops on fragmented land areas which cannot ensure their food security let alone supply marketed surplus. Associated response in farming system agriculture-related policy directions observed in that area was the new trend of using mechanization/tractors instead of manual labor, especially during the first round of land preparation.

Women's Participation in Agriculture and Benefit from Agriculture

To highlight the gender issues, secondary information taking Halaba as a case was shown below in Table 19. According to Messay (2012) in terms of land ownership in the Halaba farm community, men farmers' land ownership comes from different sources: male farmers have got 66.1% of land when they got married. This was through heritage 27.1%, 5.93% allocation, and 0.86% from leasing private farmers which clearly shows male dominance in control of resources. In terms of participation, men and women have different levels of participation in gender roles in various agricultural activities; such as level participation in cereal production for consumption.

Women had low access to improved agricultural inputs (fertilizer, improved seed, and insect pesticides) as compared to male partners. Women's participation in agricultural extension service is 9% and access to farmers' training ranges from 20.3% to 29% This is an indication of the low benefits of women in the agriculture sector.

Table 19: Summary of participation in agricultural activities

activities	**Household members**			
	Men	Women	Boys	Girls
ploughing	91.8%	0%	8.2%	0%
Sowing	96.6%	0%	3.4%	0%
Weeding	44.9%	21.8%	33.3%	0%
Activity	Household members			
	Men	Boy	Women	Girls
Cereal crop production	71.1	12.4	15.3	1.2
Cash crop production	7.2	4.8	69.5	18.5
Livestock production	16.7	58.7	58.7	b 4.6
Apiculture production	92.5		7.5	-
Poultry production				100
Daily working hours	9:30 (39.6 %) of 24 daily hours	-	14:30 (60.4%) of 24 daily hours	-

NB: Most of the daily working hours are imposed on women which means women are spending a significant of time on unpaid domestic and agricultural activities. Source: Review of literature, 2021

CONCLUSION AND RECOMMENDATIONS

Conclusion

The Major means of livelihood were crop cultivation (98.44%) followed by animal rearing (93.75%) in highland and crop accounts for 94.79% and animal rearing covers 91.67% in midland areas. The Major identified farming systems were Enset and barley Based mixed farming system, Maize based mixed farming system, Coffee based mixed farming system, Agro-pastoral farming system, and Chat and enset based mixed farming systems. The major crops in the study area were maize, common bean, finger millet, teff, potato, coffee, barley, and enset. The major livestock resources were cattle, chickens, sheep, goats, and donkeys. According to the respondents, 48(30%) had physical soil and water conservation structures on their farmland.

The farming system in the study area has shown dynamism due to drivers like the use of improved varieties, the decrease of livestock resources over time, diminish in grazing areas, shifts in livestock to crop production, the disappearance of older varieties, decline of land ownership, establishment of farmers-based associations, expansion of towns, the establishment of agro-processing industries, and production and productivity-related government policies like cluster farming.

Responses of the farming systems to existing agriculture-related policy directions include the introduction of mechanization and cluster farming in the Halaba zone from the study area. Secondary information indicates despite their participation in agricultural activities, the critical factor of production, the land is given to a male by their parents when they got married and women are neglected and had low access to improved agricultural inputs. Major coping mechanisms to climate change include selling livestock, buying food, eating fewer meals, and

storing grain for the future. Major adaptation strategies include adjusting planting date, changing crop varieties, decreasing livestock owned, and changing crop type.

The major constraints in crop production were low availability of improved or hybrid seeds, increase in the price of agricultural inputs, delay of the inputs at the required time, variability in the type of crop varieties, erratic nature of rainfall, and shortage of farm implements and labor. Market-related problems were inadequate market infrastructure, lack of market information system, lack of processing units, lack of proper modern storage facility, and price.

Livestock production constraints were prevalence of livestock diseases, shortage of feed, biological limitation of indigenous breeds of animals, shortage of water inadequate, accessibility of veterinary services, deficiency of vaccine and vaccine set-up, and limited availability of quality breeding purpose bulls. Marketing-related problems were inadequate availability of credit, poor access to organized markets, absence of a market information system, and unregulated trading. Natural resource management constraints were declining soil fertility, soil erosion and loss of topsoil, drought, land shortage, deforestation, soil acidity, and lack of adequate knowledge on natural resource management practices.

Recommendations

Improving crop and livestock productivity in the study area, improving access to improved varieties and breed at the required time, working to equip farmers' awareness on the livestock disease and improved crop management practices, and working to improve the marketing market information delivery, market infrastructure and pricing strategy is important. There is a need to work on post-harvest management practices to minimize the loss of crops from weevils and other pests. In areas of natural resource management, expanding soil and water conservation and gearing attention to maintaining the already constructed ones should be worked on. There is a need to work on improving women's access to agricultural extension services by focusing on relatively penetrable sub-sectors like poultry and garden vegetables in research and development works.

ACKNOWLEDGMENTS

This study was financially supported by Hawassa Agricultural Research Centre, Southern Agricultural Research Institute. The authors thank the respondent farmers, agriculture experts, development Agents, group participants, and key informants for sharing their indigenous knowledge and invaluable time for the study.

REFERENCES

Agricultural Growth Program. 2010. "Capacity Building and Training Manual". Retrieved Nov 9, 2021 (http://www.cida-ecco.org/AGP-CB-Manual-final.pdf)

Alemu Lelago, Tekalign Mamo, Wassie Haile, and Hailu Shiferaw. 2016. Characterization of Farming Systems in Kedida Gamela, KachaBira, and DamboyaWoredas (Administrative Districts) in Southern Ethiopia.

Ahmed Mohammed .2017. Factors affecting sweet potato production in crop-livestock farming systems in Ethiopia. The Norwegian University of Life Science. Master's Thesis, 60 ECTS Department of Plant Sciences. p46. Mekele, Ethiopia, and Norway.

AWAO. 2007. Annual Report. Arbegona, Ethiopia 18-22.

Aynalem Adugna, 2014. Ethiopian Demography and Health: A Brief Introduction.

CSA (Central Statistics Agency). 2018. Key Finding of Agricultural Sample Survey 2018, Addis Ababa, Ethiopia. (http://www.csa.gov.et/).

Dixon, JA., Gibbon D.P., and Gulliver, A., 2001. Farming systems and poverty: Improving farmers' livelihoods in a changing world.

Feleke Assefa, Teka Tadesse and Abeba Dancho. 2015. Challenges and Opportunities of Village Poultry Production in Arbegona Garemba forest District, Sidama Zone, Southern Ethiopia. Department of Animal and Range Sciences, College of Agriculture, Wolaita Sodo University, Addis Ababa, Ethiopia.

Mesay Tegegn, 2012. An assessment on the role of women in agriculture in southern nation nationality people's region: The case of Halaba special woreda, Ethiopia. M.sc. thesis, Indira Gandhi National Open Univerisity, New Delhi, India.145pp.

Pasquet, J., 2007. Participatory management on irrigation systems.: Farming systems research final report. Groupe urgence Rehabilitation et Developpement, Kabul.

Roberts, Cleophelia and Azzarri, Carlo (2014) "Ethiopia Agricultural Snapshot 2011/12," Working Paper, Harvest Choice International Food Policy Research Institute (IFPRI).

Tesfahun Fentahun and Temesgen Gashaw. 2014. Analysis of rainfall and temperature data to determine climate change in Dilla Zuria District, Southern Ethiopia. Civil and environmental research, 6(7), pp.39-42.

USAID (United States Agency for Internationa Development), 2005. Ethiopia Southern Nations, Nationalities and Peoples Region (SNNPR) Livelihood Zone Reports.

Yoseph Halala, Zeleke Afato, and Andargachew Gidebo. 2016. Determinants of food security in rural households intervened with food security program: The case of Boricha Woreda in Sidama Zone, Southern Ethiopia.

Global Research in Environment and Sustainability
December 2023, Vol. 1, No. 10, pp. 37-46.

Crop Diversification and Specialization: Drivers, Impacts on Climate Change Mitigation and Food Security of Small Holder Farmers in Ethiopia

Talila Garamu & Tadesse Tashome

1. Bioversity International Winner Varieties project OSE

Abstract:
Crop diversification and among smallholders is incompatible with maintaining or improving household food security specifically when cash crops (specialization) are included in the new crop mix. To address this problem, review the effects of crop diversification and specialization on climate change and food security of the small holder farmers. A lot of findings suggested that crop specialization has significant negative effect on the food security, climate change mitigation and environmental maintenance of smallholder farmers, while the few findings concluded that it has positive effect due to mechanization and commercialization or market orientation which targets on high value crops while the crop diversification positive effect on food security, climate change mitigation and economic benefit of the small holder farmers Reports included preconditions for choice of production systems like the availability of farm size, agro ecology, climatic condition, food security status and overall economy the farmers. Thus, extension approach should have to consider those preconditions to indicate appropriate crop production system whether Crop specialization and Diversification is very important to the particular area, to improve food security of smallholder farmers and to mitigate the climate change.

Keywords: Crop specialization, Crop diversification, Food security, Smallholder farmer

INTRODUCTION

Agriculture plays a critical role in livelihoods, employment, income growth, food security, poverty alleviation, socio-economic development and environmental sustainability in developing countries (IFPRI, 2005; World Bank, 2008). In Ethiopia, about 80% of the population lives in rural areas and depend on agricultural activities (GoE, 2011). This indicates the significance of the sector for the employment and food security of rural people and the country at large. The smallholder farms accounted for about 96% of the total cultivated area while the rest was cultivated by large commercial farms and in terms of output the smallholder accounts for 95% of total agricultural production in Ethiopia (MoANR, 2016). In Ethiopia agricultural production and productivity were low due to; insufficient and erratic rainfall, land degradation, low input application, rapid population growth and market (Zelleke *et al.,* 2010). One rational and cost-effective method may be the implementation of increased agricultural production and productivity was crop diversification. Diversification is change in product (or enterprise) choice and input use decisions based on market forces and the principles of profit maximization (Pingali and Rosegrant, 1995). Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value added crops with complementary marketing opportunities (Clements *et al.*, 2011). Crop Specialization focuses on few crops and practices considered best suited to a certain agro-ecological zone and Market oriented (Stellmacher and Kelboro, 2019). Then the crop production

system is diverted from diversification into specialization. But so many researches assured the advantage of crop diversification over specializations. Food and Agriculture Organization (FAO) policy supports crop diversification with the understanding that it may be an effective strategy for food and nutrition security, employment generation, sustainable agricultural development, environmental and ecological management, and poverty alleviation (FAO,2012).Similarly, recent Inter-national Food Policy Research Institute (IFPRI) publications have argued that growth in agricultural incomes will require diversification by farming households (Tadesse*et al.,* 2011).

Improving income and food security requires articulation of policies that encourage and support subsistence farmers to produce over and above their own needs and use their natural and human resources for high value crops that can easily be sold in the market (Niehof, 2004). From a narrow point of view, agricultural diversification implies increasing the variety of agricultural commodities produced at the farm level and is the response of subsistence farmers to reduce risks (Goletti, 1999).

Food security status of households is predominantly increased by total cultivated land and mainly decreased by land allocated to staples (Degye *et al.,* 2012). According to FAO (1996), food security is assumed to exist "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." commercial activities; and diversification from agriculture into nonfarm activities (Niehof, 2004). In crop diversification, daily calorie intake and dietary diversity also Increased (Degye *et al.,* 2012).

Different findings reported that crop diversification and specialization have their own advantage and disadvantage on crop production and food security. Crop diversification and Specialization have their own advantage and disadvantage on the smallholder farmers in Ethiopia Still now the issue of crop specialization and diversification is doubtable agenda for tackling food insecurity problem, particularly for small household farmers in Ethiopia. Even though both of the production systems have their own advantage in different aspects, the selections of appropriate production system vary depending on the land availability, topography of farm land, and agro-ecology. Because of contradicting the conclusion and recommendation on the Impacts of Crop diversification and Specialization of the production system, therefore this paper aimed to briefly highlight the impact of crop diversification and specialization on food security and Climate change mitigation

CROP DIVERSIFICATION AND SPECIALIZATION DEFINITION

Definition Crop Diversification

Crop diversification, which involves the cultivation of more than one crop including both food and cash crops, will also positively affect food security. Farmers who engage in crop diversification will improve their income through the sales of cash crops and food security through own consumption and purchased food crops using the income generated from the cash crop sales (Appiah-T *et, al.* 2022). Crop diversification, be defined as an attempt to promote crop diversity by crop rotation, multiple cropping, or intercropping, with the goal of improving productivity, sustainability, and supply of ecological systems (Wezel A *et al* 2014) It could be one step toward more sustainable production systems, value chains for minor crops (Meynard JM *et al* 2018) and socioeconomic benefits. Enhanced agricultural diversity, better diverse crop rotations, mixed cropping cultivation of grain legumes in generally cereal-dominated systems, perennial leys or grassland

(Haughey, E *et,al,* 2018), and regionally adapted varieties or variety combinations are all examples of agricultural diversification strategies.

In developing countries, crop diversification is defined as the substitution of one or more agricultural products for another. Diversification in agriculture can be defined as the reinvestment of some farm productive resources, such as land, capital, farm equipment, and labour, into new enterprises (Anamika Barman *et, al.* 2022) A shift from less profitable cropping system to more profitable cropping system is also known as diversification. Diversification of agriculture, in general, refers to transitioning from a single crop's regional or temporal dominance to the production of a variety of crops in order to meet the ever-increasing need for cereals, pulses, oilseeds, fibers, fuel, and feed. Crop diversification is a demand-driven, need-based situation specific and national goal seeking dynamic and iterative concept that incorporates spatial, temporal, value addition, and resource-complementary techniques, as well as a move from traditional and less-remunerative crops.

Definition of Crop Specialization

Crop Specialization focuses on few crops and practices considered best suited to a certain agro-ecological zone (Stellmacher and Kelboro, 2019). Market oriented production enforces the producers to produce the only marketable product. Then the crop production system is diverted from diversification into specialization. But so many researches assured the advantage of crop diversification over specializations. Food and Agriculture Organization (FAO) policy supports crop diversification with the understanding that it may be an effective strategy for dealing withissues as varied as food and nutrition security, employment generation, sustainable agricultural development, environmental and ecological management, and poverty alleviation (FAO,2012).Similarly, recent Inter-national Food Policy Research Institute (IFPRI) publications have argued that growth inagricultural incomes will require diversification by farming households (Tadesse*et al.,* 2011).

CROP DIVERSIFICATION AND SPECIALIZATION DRIVERS

Policy and Market Driver

Increased household income in most cases leads to improved resilience, especially against market, climate shocks, and better nutritional outcomes. Both on-farm diversification and specialization can contribute to more diverse and stable earnings; yet, they are dependent on access to functioning markets where surplus crops can be sold for profit. Access to markets, in turn, enables households to choose from a larger variety of foods and thus to diversify their consumption further Specialization focuses on few crops and practices considered best suited to a certain agro ecological zone, Market oriented production enforces the producers to produce the only marketable product this production system is diverted from diversification into specialization. Market information affects the level of diversification positively and significantly. According to Rehima *et, al.* (2015) reports Households who had access to market information increased their level of diversification by 39.43%. This implies that market information may decrease the uncertainty of the households associated with crop diversification. The findings of this study are consistent with other studies that reported that market information affected positively the diversification of paddy to vegetables in Thailand and crop diversification in Ethiopia (Pitipunya, 1995; 2011; Rehima *et al*., 2013). Access to market information significantly affects crop diversification at 10% probability level (Wondimagegn *et al*., 2011). Households having access to market information are more likely to diversify their production since they have the information related to supply, demand and prices of most crops. It is evident from the result

that households who own farm machinery (water pump) are more likely to diversify because they can properly perform different farming operations on time and can market their produce easily. The variable is significant at 5% probability level and the result is consistent with the finding of Muhammed *et al.* (2008). Owning machinery (water pump) is related to an increase in probability of crop diversification by 0.29% and the intensity by 3.85% on average (Wondimagegn *et al*., 2011).

The most common market interventions are food reserve purchases and agricultural input support programs most often in the form of subsidies which incentivize the production of a few staple crops (Gebremedhin and Jaleta 2012) On the other hand, when infrastructure is poor and markets imperfect or missing farmers tend to diversify to better manage their risks and to ensure basic food security (Mofya-Mukuka and Hichaambwa 2016). The provision of services such as energy, extension, water, and credit can also influence production decisions (World Bank 2008).

Policies and institutions can influence farmers' decisions through different measures, such as subsidies, taxes, agricultural support schemes, investments in research and rural training programme. The effect of agricultural extension services on the adoption of diversified farming systems was the most studied variable within the policy and institutional context. Agricultural trainings are not only a source technical knowledge and skills, but can promote and create awareness about the potential benefits of diversification and the adoption of new varieties Moreover, rural extension can be a channel to access new planting material (Williams *et al.* 2018) and a source of updated information about market opportunities, new technologies, climate change and risk management strategies (McCord *et al.* 2015)

Environmental Drivers

Agroecological zones, climate, natural resources, the prevalence of pests or diseases and shocks are key environmental drivers of agricultural production decisions in SSA, Farmers tend to focus on one crop which is adjusted to the agro-climatic condition. For example, tea, wheat, oats, and barley are grown in cool, wet areas, and rice in valleys of hot and wet regions such as swamps and marshlands. The Long growing season, Poor environmental conditions and soils Climate shocks and other agricultural risks was the positive impact on the crop diversification and Negative Impact on the crop specialization (Heumesser, C., & Kray, H.)

Topographic features, such as altitude and slope, affect other environmental characteristics like temperatures, soil erosion, wind and solar radiation exposure, but also the accessibility to farms and roads. According to Fan *et al*. (2019); Rayol *et al*. (2019), study the topography had significant association with the crop diversity (farmland slope may drive diversification, as uneven conditions of agricultural land require the farmers to adapt by growing the appropriate crop combination for each area (Abebe *et al*. 2013; Schroth and Ruf 2014). This is one of the cases in which diversification becomes more a necessity than a choice.

According to Rehima *et, al.* 2015 findings reveal that land size affected crop diversification decision of the households positively and significantly as well as increase in the area of cultivated land by one hectare increases the probability of diversification by 15.82%. This implies that large farm sizes may enable households to allot their land to multiple cereal crops than smaller holdings. Previous studies indicated that land size positively affected crop and variety diversification (Benin *et al.,* 2004).

Socio Economic Drivers on Crop Diversity and Specialization

Socio-economic drivers are defined as aspects or features that typify a group of people in a community or society that constrain or facilitate the productive diversification at the household level; institutional drivers are constructions or arrangement that exists in a society that may either constrain or facilitate productive diversification. Examples of socio-economic drivers include, among others, the level of education, gender, market access, status and income, and knowledge about the nutritional value of foods. Examples of institutional drivers include, among others, the rules, norms, and routines that guide the behavior of people in a society or in a community, as well as the distribution of power in decision-making

ROLE OF CROP DIVERSIFICATION AND SPECIFICATION ON THE CLIMATE CHANGE RESILIENCE

In an effort to adapt the risky environment, smallholders make certain production decisions and employ various risk mitigating strategies. Crop diversification is one method of reducing; the climate adaptation programmes (Isabel López *et, al.* 2017). In particular, crop diversification results showed that the farmers use of diversification strategies was more frequent in flood prone areas (Mandal and Bezbaruah 2013), subjected to a strong incidence of droughts (Asfaw *et al.* 2018), previous extreme weather events or shocks (Huang *et al*. 2014; Nguyen *et al*. 2017; Tesfaye and Tirivayi 2020). Several studies report that the crop diversification can mitigate the global climate change (Labeyrie *et,al* ,.2021).

Crop switching and diversification have been presented among key climate change adaptation strategies (Beyer *et al.,* 2022; Rising & Devineni, 2020). However, the potential for transforming or maintaining diversified agricultural systems depends on the ability of the 'new' or added crops to complete their cycle with reasonable production outcomes in the targeted areas which is referred to as their suitability (Sloat *et al.,* 2020). Diversifying cropping systems is a transformational adaptation strategy required for areas where climate change impacts are projected to be severe that stabilizing yields under a changing climate is not feasible (Rippke *et al.,* 2016). Farming households in Sub-Saharan Africa are often exposed to significant risk of climate-related shocks due to the crop Specification rather than the crop diversification. Due to the large reliance on rain fed agriculture among rural farming households in Sub-Saharan Africa, their livelihoods are highly vulnerable to weather-related risks and climate change (Adhikari *et al.* 2015). Climate change is a particularly pertinent threat that is exposing African agriculture to various forms of risks, ranging from weather variability, increased frequency and severity of droughts and floods, changes in the occurrence and range of crop and livestock pests and diseases, or greater price volatility in output, input and factor markets. The direct impact of climate risks includes a drop in agricultural production (crops and livestock), while indirect effects may entail a decreasing demand for labor and increased local prices for inputs and the product itself (Thornton and Lipper 2013). According to Reardon *et al.* (2000) report to minimize the climate cause risk the crop diversification was the most practical. Freeman *et al.* (2014) indicated that specialization may pay-off in highly variable environments if a subsidy is derived from an alternative stream of resources that can act as insurance to mitigate the risk associated with high production variance. Individuals may adopt technologies, such as irrigation, that improve the availability and predictability of water for crops. Such technology could make specialization worthwhile in environments that otherwise impose severe costs on specialization and exchange. According to Wolf (1982), specialization may still prove beneficial to individuals or individuals may be coerced to specialize, even in highly uncertain environments.

EFFECT OF CROP DIVERSIFICATION AND SPECIALIZATION ON THE FOOD SECURITY OF SMALL HOLDING FARMERS

Crop diversification, which involves the cultivation of more than one crop including both food and cash crops, will also positively affect food security. Farmers who engage in crop diversification will improve their income through the sales of cash crops and food security through own consumption and purchased food crops using the income generated from the cash crop sales (Appiah-T *et, al.* 2022)

Effects of crop production diversification on nutritional intake of farmers based on the data of 3,000 households in Malawi from 2010 to 2013, and the results indicated that the improvement of crop production diversification could significantly increase farmers' intake levels of energy, protein, iron, vitamin A and zinc (Jones 2017). The World Bank (2018) further pointed out that diversified production strategies can protect agricultural production systems from the impacts of climate and market changes, and improve farmers' intake of nutrients such as protein, vitamins and minerals to enhance their nutritional health However, Mukherjee (2015) analyzed the relationship between crop production diversification and the per capita intake of energy, protein, fat and other nutrients of farmers based on the survey data of 6 villages in 3 districts of West Bengal in India, and found that the diversification of crop production has a negative correlation with the per capita intake of energy, protein and fat in each region (Yang et, al,. 1993). Crop production specialization has a significant negative impact on farmers' energy and fat intake after overcoming the endogenous problem of the model, which implies that from the perspective of nutritional intake, crop production specialization is not conducive to improving farmers' livelihood and welfare (Sun F, *et, al.* 2022)

In addition, crop diversification was found to have a positive and statistically significant impact on food security and nutrition indicators (food consumption score and household dietary diversity). This implies that besides improving productivity, increasing production and income stability, crop diversification also has a direct effect on food availability and nutrition. This is mainly because crop diversification will improve yields, bring crop yield stability and also that crop insurance effect (Mugendi Njeru 2013; Yachi and Loreau 1999), since if one crop fails the farmer can depend on the other crop. This will have a direct impact on food security and nutrition in smallholder farming systems since traditionally the main aim will be to sustain the family and selling surplus where possible. This makes crop diversification a more important climate smart option as improving food security and diet options will help in building resilience to intensifying climate change and variability effects by smallholder farmers. According to Mugendi Njeru (2013) crop diversification not only allows more efficient utilization of agro ecological processes, but also provides diversity for human diet and improve income which improves the purchasing power for the household for buying other foods. In contrast to the FAO and IFPRI finding reports, other studies neglect the importance of crop diversification over specialization for food security. Qin and Zhang (2016) observed that households in China which specialize in crop production are less poor. Similarly, Qin and Zhang (2016), reported that households to specialize in high-value crops for sale to markets. Cultivation and sale of high-value crops to high-income is aim of crop specialization. Mansanjala (2006) identified pathways through which cash crop specialization can lead to poverty alleviation. In cash cropping specialization was very important for the markets, to contribute to the development of rural financial markets through relaxed credit constraints to improve agricultural technology and may be positively associated with increased productivity in other household activities. In contrast to this, Birthal *et al*. (2015), reported use the concept of diversification as cultivation of high-value crops in India. Contrarily, Degye *et al.* (2012) reported

that crop diversification is not correlated with status of food security indicators suggesting that households' effort to diversify in their crop production pattern.

SUMMARY AND CONCLUSION

The crop diversification and Specialization problem of any society in any country directly correlated with their food production system. In case of Ethiopia is also not away from the above truth. Due to inconsistence crop production systems and agricultural policy of the country, food insecurity has been deep rooted problem which needs solidarity to tackle particularly for small household farmers. In view of these facts, this review paper aimed with the impact of crop Diversification and specialization on climate change mitigation and food security of small household farmers in Ethiopia. A lot of findings suggested that crop specialization has significant negative effect on the climate change mitigation and food security of smallholder farmers, while the few findings concluded it has positive effect due to mechanization and commercialization or market orientation which targets on high value crops. Reports included preconditions for choice of production systems like the availability of farm size, agro ecology, climatic condition, food security status of overall economy the farmers. Crop diversification is positive effect on the greater diversity of crop and animal genetic resources and soil biota on the farm and across the wider agro-ecosystem. Biodiversity increases the resilience of agro-ecosystems to climate-related stressors and shocks by providing a variety of traits such as drought- or cold-tolerance, and by generating key ecosystem services such as nutrient cycling, soil carbon sequestration, or biological pest and disease control, among others Thus, extension approach and policy makers should have to consider those preconditions to indicate appropriate crop production system in a particular area, to improve the productivity of crop through diversification for food security of smallholder farmers and climate change mitigation

REFERENCE

Abebe, T., Sterck, F. J., Wiersum, K. F., & Bongers, F. (2013). Diversity, composition and density of trees and shrubs in agroforestry homegardens in Southern Ethiopia. *Agroforestry Systems*, *87*(6), 1283–1293. *https://doi.org/10.1007/s10457-013-9637-6/metrics*

Adhikari, U., Nejadhashemi, A. P., and Woznicki, S. A. 2015. Climate change and eastern Africa: a review of impact on major crops. Food and Energy Security 4(2): 110–132

Appiah-Twumasi, M., Maxwell, ·, & Asale, A. (2022.) Crop diversification and farm household food and nutrition security in Northern Ghana. *Environment, Development and Sustainability*. https://doi.org/10.1007/s10668-022-02703-x

Asfaw S, Pallante G, Palma A (2018) Diversification strategies and adaptation deficit: evidence from rural communities in Niger. World Dev 101:219–234. *https://doi.org/10.1016/j.worlddev.2017.09.004*

Barman, A., Saha, P., Patel, S., Bera, A., Barman, A., Saha, P., Patel, S., & Bera, A. (2022). Crop Diversification an Effective Strategy for Sustainable Agriculture Development. *Sustainable Crop Production - Recent Advances*. https://doi.org/10.5772/INTECHOPEN.102635

Benin, S, M Smaleb, J Pender, GM Berhanu, and Ehui. 2004. The economic determinants of cereal crop diversity on farms in the Ethiopian Highlands. Agri. Econ. 31(2004): 197-208. Available: Online at www.elsevier.comflocate/agecon

Beyer, R. M., Hua, F., Martin, P. A., Manica, A., & Rademacher, T. (2022). *Relocating croplands could drastically reduce the environmental impacts of global food production*. https://doi.org/10.1038/s43247-022-00360-6

Birthal, P. S., Roy, D., & Negi, D. S. (2015). Assessing the impact of crop diversification on farm poverty in India. *World Development*, *72*, 70–92. https://doi.org/10.1016/j.worlddev.2015.02.015

Degye Goshu, Belay Kassa, and Mengistu Ketema (2012) Does Crop Diversification Enhance Household Food Security? Evidence from Rural Ethiopia. (n.d.). Retrieved April 12, 2023, https://www.researchgate.net/publication/275031635

Fan, L., Dang, X., Tong, Y., & Li, R. (2019). Functions, motives and barriers of homestead vegetable production in rural areas in ageing China. *Journal of Rural Studies*, *67*, 12–24. *https://doi.org/10.1016/j.jrurstud.2019.02.007*

FAO (Food and Agricultural Organization). 2012. Crop diversification for sustainable diets and nutrition: The role of FAO's Plant Production and Protection Division. Technical report, Plant Production and Protection Division, Food and Agriculture Organization of the United Nations, Rome

FAO .2012. Crop diversification for sustainable diets and nutrition: The role of FAO's Plant Production and Protection Division. Technical report, Plant Production and Protection Division, Food and Agriculture Organization of the United Nations, Rome. ISBN 978-92-5-107317-9

FAO. 1996. World Food Summit Plan of Action, Rome, Italy.

Freeman, J., J.M. Anderies, A. Torvinen and B.A. Nelson. (2014). Crop Specialization, Exchange and Robustness in a Semi-arid Environment on JSTOR. (n.d.). Retrieved April 12, 2023, from https://www.jstor.org/stable/24013807

Gebremedhin, B., & Tegegne, A. (2012). Market Orientation and Market Participation of Smallholders in Ethiopia: Implications for Commercial Transformation. *2012Conference, August 18-24, 2012, Foz Do Iguacu, Brazil*. https://doi.org/10.22004/AG.ECON.125847

GoE (Government of Ethiopia). 2011. 'Growth and Transformation Plan 1', Addis Ababa: Federal Democratic Republic of Ethiopia

Goletti, F., 1999. Agricultural Diversification and Rural Industrialization as a Strategy for Rural Income Growth and Poverty Reduction in Indochina and Myanmar, Paper prepared for the Symposium on "Food Policy in Indochina and Myanmar: The Effects of Globalization" co-sponsored by International Food Policy Research Institute and the Ministry of Agriculture and Rural Development, Hanoi, March 1-2, 1999

Haughey, E., Suter, M., Hofer, D., Hoekstra, N. J., Mcelwain, J. C., Lüscher, A., & Finn, J. A. (2018.). *Higher species richness enhances yield stability in intensively managed grasslands with experimental disturbance OPEN*. https://doi.org/10.1038/s41598-018-33262-9

Heumesser, C., & Kray, H. A. (n.d.). Productive Diversification in African Agriculture and its Effects on Resilience and Nutrition.

Huang JK, Jiang J, Wang JX, Hou LL (2014) Crop diversification in coping with extreme weather events in China. J Integr Agric 13:677–686. *https://doi.org/10.1016/S2095-3119(13)60700-5*

International Food Policy Research Institute (IFPRI). (n.d.). *The future of small farms | IFPRI: International Food Policy Research Institute*. Retrieved April 12, 2023, from https://www.ifpri.org/publication/future-small-farms

Isabel López, Noriega, Ian K Dawson, Ronnie Vernooy, Ilse Köhler-Rollefson and Michael Halewood (2017) Importance of agricultural biodiversity for agricultural production. *Agriculturefor Development*

Jones, A. D. (2017). On-farm crop species richness is associated with household diet diversity and quality in subsistence- and market-oriented farming households in Malawi. *Journal of Nutrition*, *147*(1), 86–96. https://doi.org/10.3945/JN.116.235879

Labeyrie, V., Renard, D., Aumeeruddy-Thomas, Y., Benyei, P., Caillon, S., Calvet-Mir, L., M. Carrière, S., Demongeot, M., Descamps, E., Braga Junqueira, A., Li, X., Locqueville, J., Mattalia, G., Miñarro, S., Morel, A.,

Porcuna-Ferrer, A., Schlingmann, A., Vieira da Cunha Avila, J., & Reyes-García, V. (2021). The role of crop diversity in climate change adaptation: insights from local observations to inform decision making in agriculture. *Current Opinion in Environmental Sustainability*, *51*, 15–23. *https://doi.org/10.1016/j.cosust.2021.01.006*

Mandal R, Bezbaruah MP (2013) Diversification of cropping pattern: its determinants and role in flood affected agriculture of assam plains. *Indian J Agric Econ 68:169–181*

Masanjala, W. H. (2006). Cash crop liberalization and poverty alleviation in Africa: Evidence from Malawi. *Agricultural Economics*, *35*(2), 231–240. https://doi.org/10.1111/J.1574 0862.2006.00156.X

McCord PF, Cox M, Schmitt-Harsh M, Evans T (2015) Crop diversification as a smallholder livelihood strategy within semi-arid agricultural systems near Mount Kenya. Land Use Policy 42:738–750. https://doi.org/10.1016/j.landusepol.2014.10.012

Meynard, J.-M., Charrier, F., M'hand Fares, &, le Bail, M., Magrini, M.-B., Charlier, & A., & Messéan, A. (n.d.). *Socio-technical lock-in hinders crop diversification in France*. https://doi.org/10.1007/s13593-018-0535-1

MoANR (Ministry of Agriculture and Natural Resources). 2016. 'Policies and Strategies', Addis Ababa, Ethiopia, www.moa.gov.et/policies-and-strategies

Mofya-Mukuka, R., & Kuhlgatz, C. (2016). Impact of Agricultural Diversification and Commercialization on Child Nutrition in Zambia: A Dose Response Analysis. *Journal of Agricultural Science*, *8*(4), p60. https://doi.org/10.5539/JAS.V8N4P60

Mukherjee, A. (2015). Evaluation of the Policy of Crop Diversification as a Strategy for Reduction of Rural Poverty in India. *Economic Studies in Inequality, Social Exclusion, and Well-Being*, 125–143. https://doi.org/10.1007/978-981-287-420-7_7

Nguyen DL, Grote U, Nguyen TT (2019) Migration, crop production and non-farm labor diversification in rural Vietnam. Econ Anal Policy 63:175–187. *https://doi.org/10.1016/j.eap.2019.06.003*

Niehof, A., 2004. The significance of diversification for rural livelihood systems, Food Policy, 29 (4):321–338. Njeru EM (2013)). Crop diversification: a potential strategy to mitigate food insecurity by smallholders in sub-Saharan Africa. *Foodsystemsjournal.Org*, *3*(4), 63–69. https://doi.org/10.5304/jafscd.2013.034.006

Pitipunya, R. (1995). Determinants of Crop Diversification on Paddy field: A Case Study of Diversification to Vegetables. *Kasetsart Journal of Social Sciences*, *16*(2), 201–208. Retrieved from https://so04.tci-thaijo.org/index.php/kjss/article/view/243725

Qin, Y., & Zhang, X. (2016). The Road to Specialization in Agricultural Production: Evidence from Rural China. *World Development*, *77*, 1–16. https://doi.org/10.1016/j.worlddev.2015.08.007

Rayol, B. P., do Vale, I., & Miranda, I. S. (2019). Tree and palm diversity in homegardens in the Central Amazon. *Agroforestry Systems*, *93*(2), 515–529. *https://doi.org/10.1007/s10457-017-0144-z/metrics*

Reardon, T., Taylor, J. E., Stamoulis, K., Lanjouw, P., & Balisacan, A. (2000). Effects of Non-Farm Employment on Rural Income Inequality in Developing Countries: An Investment Perspective. *Journal of Agricultural Economics*, *51*(2), 266–288. https://doi.org/10.1111/J.1477-9552.2000.TB01228.X

Rehima Mussema, Belay Kassa, Dawit Alemu and Rashid Shahidur (2015*)* Determinants of Crop Diversification in Ethiopia: Evidence from Oromia Region. Retrieved April 11, 2023, from https://www.researchgate.net/publication/285176325_

Rippke, U., Ramirez-Villegas, J., Jarvis, A., Vermeulen, S. J., Parker, L., Mer, F., Diekkrüger, B., Challinor, A. J., & Howden, M. (2016). Timescales of transformational climate change adaptation in sub-Saharan African agriculture. Nature Climate Change, 6(6), 605-609.

Rising, J., & Devineni, N. (2020). *Crop switching reduces agricultural losses from climate change in the United States by half under RCP 8.5*. https://doi.org/10.1038/s41467-020-18725-w

Schroth, G., & Ruf, F. (2014). Farmer strategies for tree crop diversification in the humid tropics. A review. *Agronomy for Sustainable Development*, *34*(1), 139–154. *https://doi.org/10.1007/s13593-013-0175-4/metrics*

Sloat, L. L., Davis, S. J., Gerber, J. S., Moore, F. C., Ray, D. K., West, P. C., & Mueller, N. D. (2020). Climate adaptation by crop migration. https://doi.org/10.1038/s41467-020-15076-4

Stellmacher, T. and G, Kelboro. 2019. Family Farms, Agricultural Productivity, and the Terrain of Food Insecurity in Ethiopia. *Sustainability,* 11(18):1-10.

Sun F, Qian P, Cao S, Chen Y, Feng Z (2022) The impact of crop specialization on nutritional intake: Evidence from farm households in China. PLoS ONE 17(8): e0272347. https://doi.org/10.1371/journal.pone.0272347

Taddesse, A. S., Dorosh, P., & Asrat, S. (2011). *Crop Production in Ethiopia: Regional Patterns and Trends Ethiopia Strategy Support Program II (ESSP II)*. www.ifpri.org

Tesfaye W, Tirivayi N (2020) Crop diversity, household welfare and consumption smoothing under risk: evidence from rural Uganda. World Dev 125:104686. *https://doi.org/10.1016/j.worlddev.2019.104686*

Wezel, A., Casagrande, M., Celette, F., Vian, J. F., Ferrer, A., & Peigné, J. (2014). Agroecological practices for sustainable agriculture. A review. *Agronomy for Sustainable Development*, *34*(1), 1–20. https://doi.org/10.1007/S13593-013-0180-7/METRICS

Williams NE, Carrico AR, Edirisinghe I, Jayamini Champika PA (2018) Assessing the impacts of agrobiodiversity maintenance on food security among farming households in Sri Lanka's Dry Zone. Econ Bot 72:196–206. https://doi.org/10.1007/s12231-018-9418-2

Wolf, E.R. 1982. Europe and the people without history. University of California Press, Berkeley

Wondimagegn M, F Bekabil, and H Jema. 2011 Pattern, Trend and Determinants of Crop Diversification: Empirical Evidence from Smallholders in Eastern Ethiopia | Request PDF. Retrieved April 11, 2023, from https://www.researchgate.net/publication/265754761

World Bank (2008) *World Development Report 2008*. https://doi.org/10.1596/978-0-8213-6807-7

World Bank. (2021). *Documents & Reports - All Documents | The World Bank*. Retrieved April 12, 2023, from https://documents.worldbank.org/en/publication/documents-reports

Yachi, S., & Loreau, M. (1999). Biodiversity and ecosystem productivity in a fluctuating environment: The insurance hypothesis. *Proceedings of the National Academy of Sciences of the United States of America*, *96*(4), 1463–1468. https://doi.org/10.1073/PNAS.96.4.1463

Yang, Xiaokai., & Ng, Y.-Kwang. (1993). *Specialization and economic organization: a new classical microeconomic framework*. 507. https://books.google.com/books/about/?id=xuG4AAAAIAAJ

Zelleke G, Agegnehu G, Abera D, Rashed, S. 2010. Fertilizer and Soil Fertility Potential in Ethiopia: Constraints and opportunities for enhancing the system paper prepared for presentation at the international association of Agriculture. 9

Global Research in Environment and Sustainability
December 2023, Vol. 1, No. 10, pp. 47-58.

Photocatalytic Degradation of Gentian Violet Using Doped Zinc Oxide Nanoparticles

Okwuolise, G.[1], Oguzie, E. E.[1&2], & Emereibeole, E. I.[1]

1. Department of Environmental Management, Federal University of Technology, Owerri, PMB 1526, Imo State, Nigeria
2. African Centre of Excellence in Future Energies and Electrochemical Systems (ACE-FUELS), Federal University of Technology, Owerri, PMB 1526, Imo State, Nigeria

Abstract:
This research was carried out to investigate the photocatalytic degradation of Gentian Violet dye using doped zinc oxide nanoparticles as catalyst. The photocatalysis was carried out under UV-irradiation and in dark which serves as control. The morphological structures of nanomaterials were investiged by X-ray diffraction (XRD) and scanning electronic microscope (SEM). The absorption spectra wavelength and absorption edge wavelength of the as-synthesized photocatalyst was determined by UV- Visible spectrophotometer. The effect of catalyst dosage on the degradation process was assessed by varying the catalyst from 0.1-0.4g/100ml. Results reveal catalysts doses of ZnO nanoparticles 0.3g/100ml dose with the percentage degradation (ZC 71.5%, ANZ 94.5%, AZ 76.5%, NZ 91.2%) as the most suitable catalyst dosage for degrading GV under UV irradiation at 120 mins time. The result also shows that the highest percentage of photocatalytic degradation was achieved using silver-nitrogen co-doped zinc oxide photocatalyst (ANZ) both under solar and Uv irradiation. Under solar irradiation NZ tend to give better degradation than (AZ). Photocatalytic degradation in the dark is negligible. Degradation of gentian violet dye in the absence of light was performed to demonstrate that the presence of light and catalyst was essential for the photo degradation to occur.

Keywords: Dyes, Gentian Violet, Zinc Oxide Nanoparticles, Photocatalytic Degradation, Textile Wastewater Treatment, Gentian Violet.

INTRODUCTION

Dyes are widely used in various industries, including textile, paper, leather, and cosmetics. The discharge of dye-containing wastewater into water bodies can result in decreased aesthetic value of water, decreased light penetration, and toxic effects on aquatic organisms. Some dyes and their degradation by-products are known to be carcinogenic, mutagenic, and toxic to aquatic organisms (Sudarshan *et al.*, 2022). Wastewater pollution and inadequate wastewater treatment pose significant environmental challenges globally. The discharge of untreated or inadequately treated wastewater, as well as the presence of dyes in wastewater, can have detrimental effects on ecosystems, human health, and water resources. The presence of a trace amount of colored organic compounds in the aquatic system can result in coloration of the water. The consequence of colored water is detrimental to aquatic environment since the color obstructs the sunlight access to aquatic organisms and plants, diminishing the photosynthetic process thereby affecting the entire aquatic ecosystem (Senthilvelan *et al.*, 2013). Therefore, the removal of color and sanitization has become an ecological concern and is vital for environmental sustainability. Industrial development and its association with discharge of organic matter into the aquatic systems demand technological development to solve the environmental problems related to

organic effluents (Zhou, 2013). Many practices have been widely applied in the treatment of organic effluent such as biological treatment, reverse osmosis, ozonation, filtration and adsorption on solid phases, incineration, and coagulation (García-Montaño, 2008). However, each of the methodologies has their limitations. Incineration can result in deadly toxic volatiles products (Vinita and Dorathi, 2010); biological treatment needs prolonged treatment time and results in ghastly smell; ozonation can be effective way for the treatment of organic effluent but the stability of ozone is the biggest concern which is highly influenced by the existence of salts, pH, and temperature (Vinita and Dorathi, 2010). The traditional physical methods (adsorption, filtration, reverse osmosis and coagulation) are quite expensive and do not eliminate the organic molecules utterly but just transform them from one phase to another (Zelmanov and Semiat, 2008).

In recent era, advanced oxidation processes (AOPs) have been found as an effective and alternative way for the treatment of organic effluent in aqueous system (Boczkaj and Fernandes, 2017). Recent researches have demonstrated that AOPs based on photocatalysts are valuable and employs complete mineralization of organic molecules into nontoxic CO_2 and H_2O at the atmospheric conditions (Vinu and Akki, 2010). Furthermore, AOPs result in the generation of hydroxyl radicals (•OH) as main oxidizing agents which can remove even nonbiodegradable organic compounds from wastewater stream (Xia *et al*., 2020). Photocatalytic degradation of organic effluent emerged as one of the best methodologies for the treatment of toxic organic effluents which uses the semiconductor as catalyst such ZnO, TiO_2, ZnS, WO_3, CdS, Fe_2O_3, and $SrTiO_3$ (Sathishkumar, 2013). Among them ZnO and TiO_2 have been widely applied as photocatalyst due to their high activity, nontoxicity, chemical stability, lower costs, optical and electrical properties, and environment friendly characteristics (Xia *et al*., 2020). It is against this backdrop that it becomes imperative to investigate the photocatalytic degradation of Gentian violet using doped zinc oxide nanoparticles.

MATERIALS AND METHODS

The synthesis of Zinc Oxide, Silver Doped Zinc Oxide, Nitrogen Doped Zinc Oxide and Silver Nitrogen Co-Doped Zinc Oxide Nanoparticles was carried out in Federal University of Technology Owerri, FUTO, Nigeria. The UV visible diffuse absorbance spectra characterization was also carried out at Federal University of Technology Owerri, FUTO. SEM analysis was carried out at Ahmadu Bello University, Samaru Campus, Zaria, Nigeria and the XRD analysis was carried out at national steel raw materials exploration agency, Kaduna, Nigeria.

Materials and Apparatus

The materials and apparatus used where X-ray diffraction with machine model: Shimadzu XRD, model 6000, Scanning Electron Microscope (SEM): Phenom prox, model no MVE 016477830 manufactured by PhenomWold Eindhoven Nethalands, LASANY UV-VIS spectrophotometer LAB 722, PH meter, Artificial UV irradiation system, crucibles, beakers, analytical weighing balance, desiccators, volumetric flask, measuring cylinder, muffle furnace, oven ceramic mortar, spatula, quartz curvette, syringe. Whatman filter paper, centrifuge, magnetic stirrer, shaker and glass rod.

Chemicals Used

The chemicals used in the experiment was, Burgoyne zinc oxide, kernel urea, deionized water, sodium hydroxide (NaOH). Hydrochloric Acid (HCL), silver nitrate, Gentian Violet dye.

Methods

Synthesis of Photocatalysts:

Preparation of Zinc Oxide Nanoparticles (Zc):

Pure 60g of Burgoyne pure Zinc oxide reagent was measured using analytical weighing balance; the weighed zinc oxide was placed in a ceramic crucible, then placed in a muffle furnace and calcined for four (4) hours at 600°C. It was then cooled to room temperature, ground in a mortar and labeled as calcine zinc oxide (Zc).

Preparation of Nitrogen-Doped Zinc Oxide (Nz):

40g of uncalcined Zinc Oxide was measured using analytical weighing balance and 80g of urea was also measured. The weighed Zinc Oxide and Urea was placed in a ceramic crucible and agitated vigorously with a glass rod, the mixture was placed in a muffle furnace and calcined for four (4) hours at 600°c. It was cooled to room temperature, grinded in a mortar and labeled NZ.

Plate 1: calcined nitrogen doped Zinc.

Preparation of Silver-Nitrogen Co-Doped Zinc Oxide Nanoparticles (ANZ):

4.5g of silver nitrate was measured using analytical weighing balance and mixed with 250ml of distilled water in a volumetric flask. 20g of Nitrogen doped Zinc Oxide was measure and put in a crucible, 20ml of silver nitrate was also measured using measuring cylinder and put into crucible containing 20g of Nitrogen-Doped Zinc Oxide. The mixture was then agitated with glass rod and placed in an oven for 30 min at 120°c. It was then placed in a furnace for four (4) hours at 600°c, cooled to room temperature and grinded to fined particles and labeled ANZ.

Preparation of Silver Doped Zinc Oxide Nanoparticles (AZ):

20g of uncalcined Zinc Oxide was measured using analytical weighing balance and placed in a crucible. 20ml of silver nitrate was measured using measuring cylinder and mixed with 20g of uncalcined Zinc Oxide. The mixture was then agitated with a glass rod and placed in an oven for drying for 30min at 120°c. It was then calcined in a furnace for four (4) hours at 600°c. It was then cooled to room temperature and grinded to fined particles and labeled AZ.

Plate 2: calcined silver doped zinc

Characterization of Photocatalysts:

To observe the absorption edge of the as-synthesized photocatalysts, UV-Vis absorption spectra was measured using LASANY UV spectrophotometer LAB 722 at Federal University of Technology, Owerri. 0.1 g of the photocatalyst was dissolved in 10 ml of deionized water. The UV Visible spectrometer was turned on and made the baseline using the deionized water. Then the absorbance of the photocatalyst solution was measured using a quartz tube. For determining the crystallite size of the as-synthesized photocatalysts, X-ray diffraction (XRD) analysis was carried out at national steel raw materials exploration agency, Kaduna. The machine model is Shimadzu XRD, model 6000, using a Cu target Kα (λ = 1.5406 Ao) with measurements made at room temperature and Scanning Electron Microscope (SEM). For determining average particle size of as-synthesized photocatalyst, analysis was carried out at Ahmadu Bello University, Zaria with machine model: Phenom prox, model no MVE 016477830 manufactured by PhenomWold Eindhoven Netherlands.

Photocatalytic Degradation Studies:

For each Photocatalyst:

0.1-0.4g of photocatalyst was ultrasonically dispersed in Gentian Violet aqueous solution and agitated in the dark for 30min to ensure the adsorption/desorption equilibrium of GV aqueous solution with the catalyst. The mixture was then loaded in an open beaker exposed to UV light from a low-pressure lamp (Philips 15 W) positioned parallel to reactor. UV–Vis absorption spectra of samples were measured at regular intervals of 30 min to monitor the reaction of GV aqueous solution decolorization, and the absorption range of 350–800 nm was recorded as a function of irradiation time. The 10 mL suspension withdrawn at 30 min interval was centrifuged for 15 min and filtered using Whatman No. 1 filter paper to remove the catalyst particles, if any, before recording the absorbance at _max = 590 nm using UV/Vis spectrophotometer. Percentage degradation of GV was calculated using the relation (Kang *et al.*, 2010):

$$\% \text{ degradation} = [(A_o - A_t)/A_o] \times 100$$

Where Ao is absorbance of dye at initial stage, A_t is absorbance of dye at time "t". The Photocatalytic Degradation study was carried out using the procedure described by Tesfay. Experiment Variable included.

RESULT AND DISCUSSION

UV Spectral Characterization

The optical absorption spectra of photocatalysts i.e. (Zc, AZ, NZ and ANZ) are depicted in Figures (1-5). UV-Visible absorption spectra for Zc, AZ, NZ and ANZ are: 373, 423, 473, and 523 nm, respectively. UV-Vis absorption spectra of NZ and ANZ photocatalysts are well extended to visible region spectrum compared to Zc and AZ. This may be due to the modification of electronic levels of zinc oxide by nitrogen-doping.

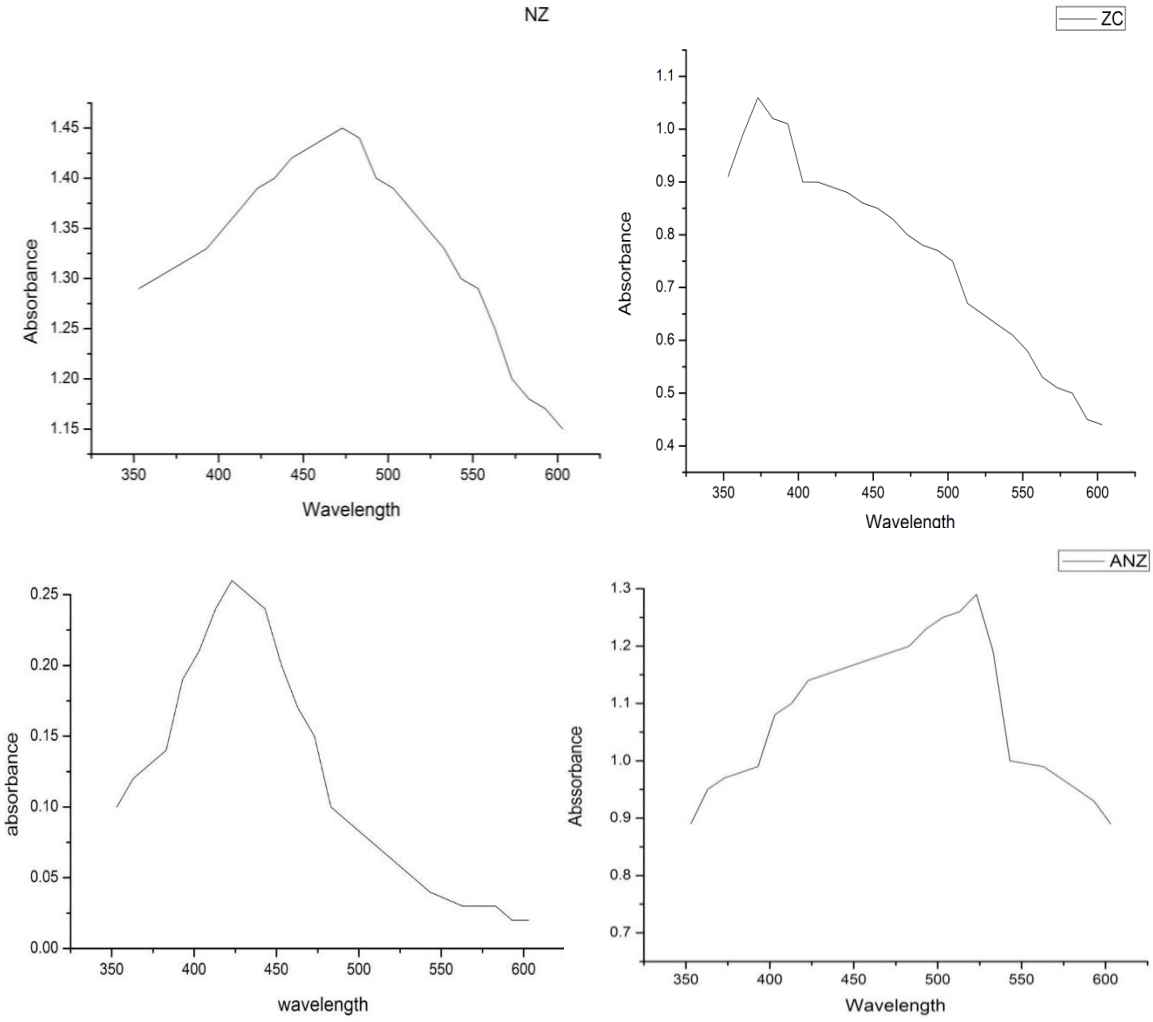


Figure 1 4.1: UV-Visible absorption spectra of Nitrogen doped zinc oxide, zinc Oxide, silver doped zinc oxide and nitrogen doped- silver co-doped zinc oxide.

Band gap energy of the as-synthesized photocatalysts was obtained using the relation (El-Kemary *et al.*, 2010). Eg (eV) = [1240/λ] Where Eg is band gap energy in electron volts, λ is wavelength (nm) corresponding to absorption spectra. The band gap energies (Eg) of photocatalysts Zc, AZ, NZ, and ANZ were found as 3.32, 2.93, 2.62, 2.37 eV, respectively. Nitrogen-doping in zinc oxide resulted significant decrease of band gap energy of NZ and ANZ Incorporation of silver in Zc caused comparatively smaller change relative to nitrogen incorporation. It may be because of doped silver adheres near the surface of zinc oxide and does not modify the band gap energy of

zinc oxide (Ren *et al.*, 2010). Silver only traps the electrons and prevented from recombination of electrons in the conduction band and holes in the valence band (Aal *et al.*, 2009).

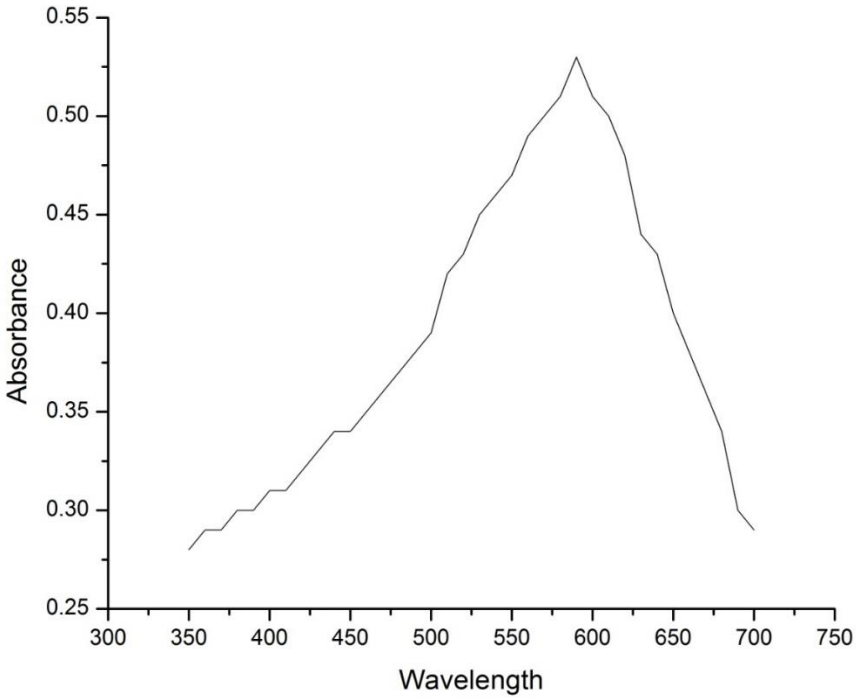


Figure 2: Plot of Graphs of Absorption Edge of Gential Violet Dye on UV-VIS Spectrophotometer

X-Ray Diffraction

The XRD characterization was performed to show the crystalline structure of the ZnO photocatalysts. The peaks at 2θ values of 24.09°, 24.39°, 27.64°, 27.76°, 64. 31°, 37°, 35.44°, 49.27°, 49.46°, 52.26°, 59°.38°, observed in the XRD spectra of ANZ are indicative of the typical hexagonal wurtzite structure of ZnO. (According to (JCPDS NO.20-0781). An XRD spectrum of silver-doped zinc oxide (AZ) is the exact reproduction of the spectra of calcined zinc oxide (Zc). It suggests that doped silver atoms may be located just at the zinc oxide crystal surface rather than at lattice sites in zinc oxide. Therefore, it may not alter its crystal structure. XRD spectra of nitrogen-doped zinc oxide (NZ) showed slight strong and broad diffraction peaks. In case of silver nitrogen co-doped zinc oxide (ANZ); its XRD spectra (Figure 3) again have narrow and sharp diffraction peaks. The difference in the XRD spectra of nitrogen-doped zinc oxide and silver-nitrogen co-doped zinc oxide may be attributed to the difference in their calcination's periods and the doping nature. The former (NZ) sample was calcined only for 4 hours whereas the later (ANZ) sample was calcined for much longer periods (8 hours). A prolonged thermal treatment in case of ANZ may induce crystallinity. The crystallite size of as-synthesized photocatalysts are: Zc (20) AZ (10.71) ANZ (10.16 nm) NZ (11.44 nm). Lower size of ANZ than Zc and AZ may be due to longer time of calcinations in case of ANZ. The size of ZnO nano is calculated.

By using Scherrer's formula,

$$D = 0.9\,\lambda / B\cos\theta$$

Where,
K= constant (0.9)

λ= Radiation of wavelength
β= FWHM (Full Width Half Wave Maxima)
θ= Bragg angle in degree
D= Particle Size.

Scanning Electron Microscope

SEM Micrograph Analysis:

Plates 3-6 show the micrograph images of the prepared Photocatalyst. The surface morphology of ZnO, photocatalyst has been studied using High Resolution Scanning Electron Micro graphs. The SEM investigations revealed that the synthesized particles were of nanometer size in all of the samples.

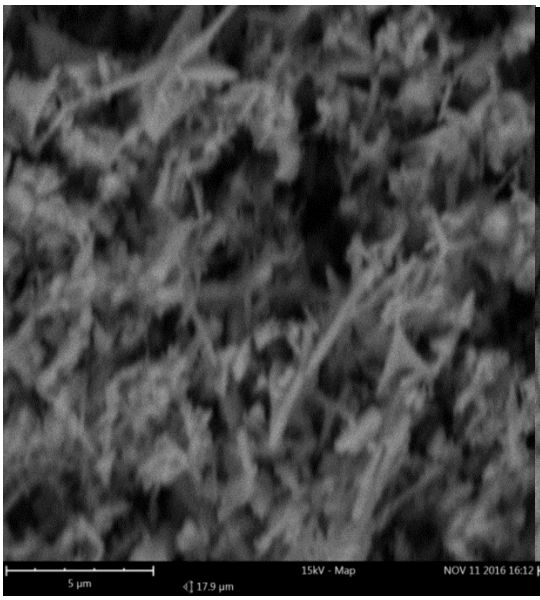


Plate 3: SEM Silver doped Zinc oxide

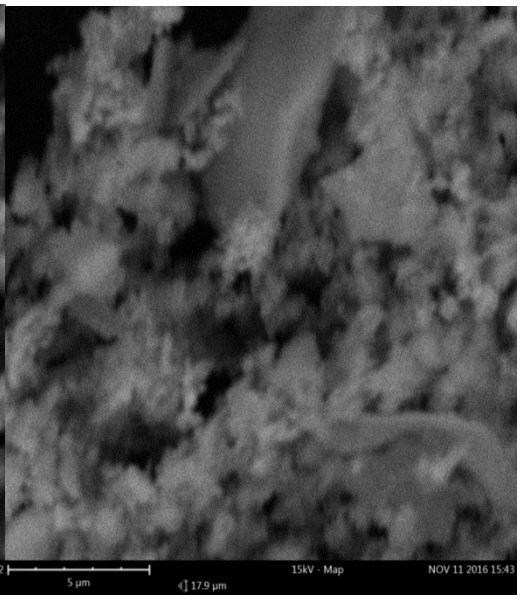


Plate 4: SEM Nitrogen doped Zinc oxide

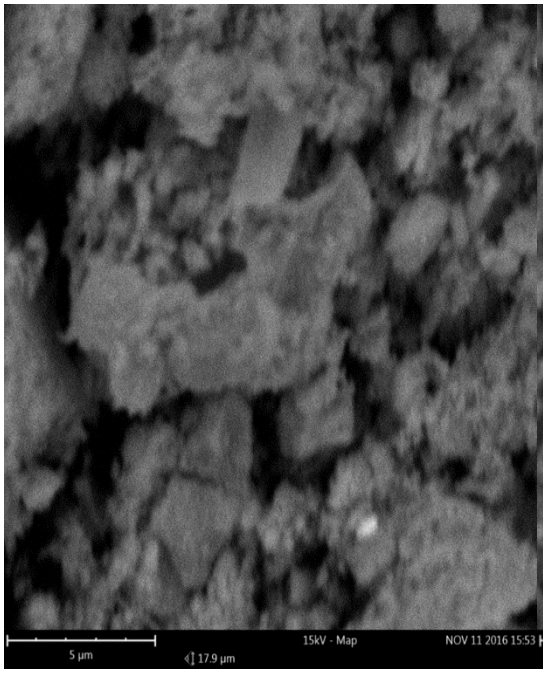


Plate 5: SEM Silver Nitrogen doped Zinc oxide

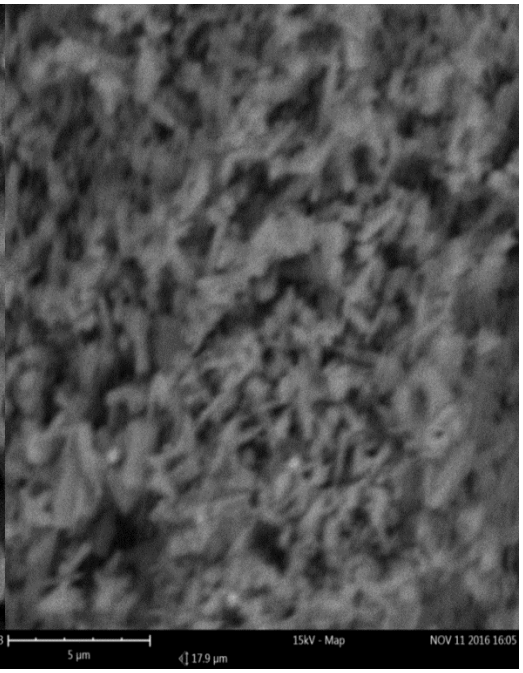


Plate 6: SEM Zinc Oxide

ZnO image indicates that the highly dispersed nano materials have been obtained with an average diameter of 50 nm. The nitrogen doped ZnO exhibits hexagonal shaped nanoparticles and are highly aggregated such agglomeration makes it difficult to evaluate the grain size from SEM images and average diameter was calculated as 40 nm. In the case of AZ and ANZ, shows that the hexagonal shaped nano materials grew in high density. The average diameter of the grown nanomaterials was about 45 and 50nm

Photocatalytic Degradation Study

The percentage adsorption of Gentian Violet without irradiation using the adsorbents: Zc, AZ, NZ, and ANZ at 120 minutes were 7.1%, 7.2%, 10.5%, and 13.2%, The percentage of photo-degradation of GV under solar and UV irradiations using these photocatalysts, Zc, AZ, NZ, and ANZ at 120 minutes were 69.2%, 71.1%, 89.4%, and 91.6, then for UV, 71.5%, 76.5%, 91.2%, and 94.5%.

The photocatalytic activity of Zc is lowest among studied photocatalysts under both UV and solar irradiations. This may be due to its small specific surface area or amorphous nature. Photocatalytic activity of AZ is higher than Zc both under solar as well as UV irradiations. It may be because doping of a noble metal, such as silver, in a semiconductor which can entrap the photo-generated electron thereby diminishing the recombination of electron-hole pairs, and thus resulting in higher photocatalytic activity of AZ. It is worthwhile to compare the photocatalytic activity of NZ and Zc under both solar as well as UV irradiations. Nitrogen doped (NZ) zinc oxide shows more photocatalytic activity than Zc. This may be due to narrowing of band gap energy on doping nitrogen to zinc oxide. It is also possible to compare the photocatalytic activity of AZ and NZ under both solar as well as UV irradiations. It is observed that under solar irradiations the percentage degradation of Gentian Violet is higher for NZ than AZ. Under UV irradiations the percentage degradation of GV solution is higher for AZ than NZ. Nonmetals such as nitrogen incorporated in the crystal of zinc oxide, may modify the electronic levels of zinc oxide resulting in its band gap narrowing, thus, rendering it more responsive to sunlight (Zheng & Wu, 2009; Li & Haneda, 2004). In case of AZ under UV irradiations, since silver can trap the photo-generated electron the recombination of electron hole pair is inhibited and thus enhancing its photocatalytic activity (Zhang & Mu, 2007). However, in case of NZ, under UV irradiations although there is equal probability of formation of electron-hole pairs since there is no other species which can trap the photogenerated electrons and hence there is lower photoactivity of NZ than AZ.

The effect of ZnO photocatalyst dosage was studied. Four different amount of photocatalyst was tried, which are 0.1, 0.2, 0.3 and 0.4 g. According to the result, increase of photocatalyst amount from 0.1 g to 0.3 g will lead to an increase in percentage removal. The increase of percentage degradation by increasing photocatalyst loading is because the presence of more ready availability surface area, causing the number of active site increase and therefore enhance the photodegradation rate (Chen *et al*., 2007).

Nevertheless, it was observed that the percentage removal of Gentian Violet decreased when 0.4 g of photocatalyst was applied in the experiment. This may be due to excessive of photocatalyst leads to agglomeration and sedimentation of ZnO nanoparticles. In other words, 0.4 g of photocatalyst may be considered too much in this experiment set up. However, above the optimum concentration, the excess catalyst can inhibit illumination of the sample due to catalyst agglomeration, which effectively reduces the available surface area. Consequently, the degradation rate will decrease. The other possible cause of the reduced photocatalytic

degradation rate is absorption of scattered light by the excess of catalyst, which then could increase the optical density in the active site of the catalyst. (Kapinus, 2010)

For Comparison Studies, Table 1-3 illustrated the effect of dosage on the photocatalytic degradation of gentian violet under UV, Solar and No irradiation.

Table 1: Comparison Table of Photocatalyst Dosage from 0.1-0.4 at 120min under UV irradiation

Photocatalyst Dosage	ZC (%)	NZ (%)	AZ (%)	ANZ (%)
0.1	38.1	58.3	62.1	67.2
0.2	56.2	63.2	77.3	90.2
0.3	71.5	76.1	91.2	94.5
0.4	66.4	72.4	87.2	90.1

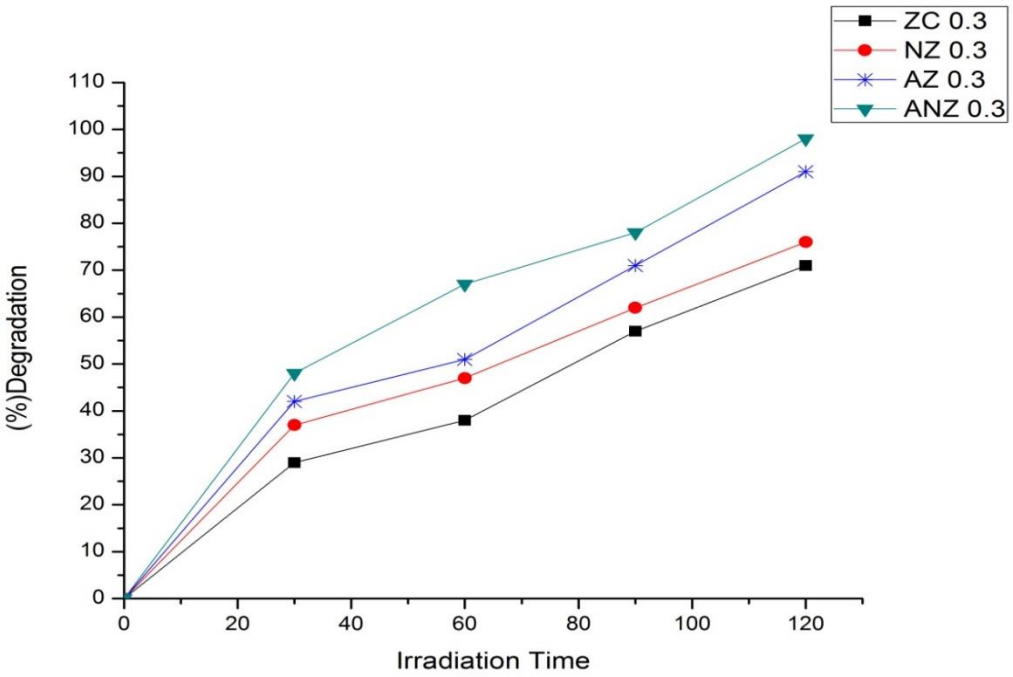


Fig. 3: Plots of Percentage Degradation of Gentian Violet as Function Of time Under UV Irradiation

Table 2: Comparison Table of Photo catalyst Dosage from 0.1-0.4 at 120min under Solar irradiation

Photocatalyst	ZC (%)	AZ (%)	NZ (%)	ANZ (%)
0.1	39.2	53.2	55.1	60.1
0.2	52.3	55.1	73.2	79.3
0.3	69.2	71.1	89.4	91.6
0.4	59.1	78.3	81.1	87.3

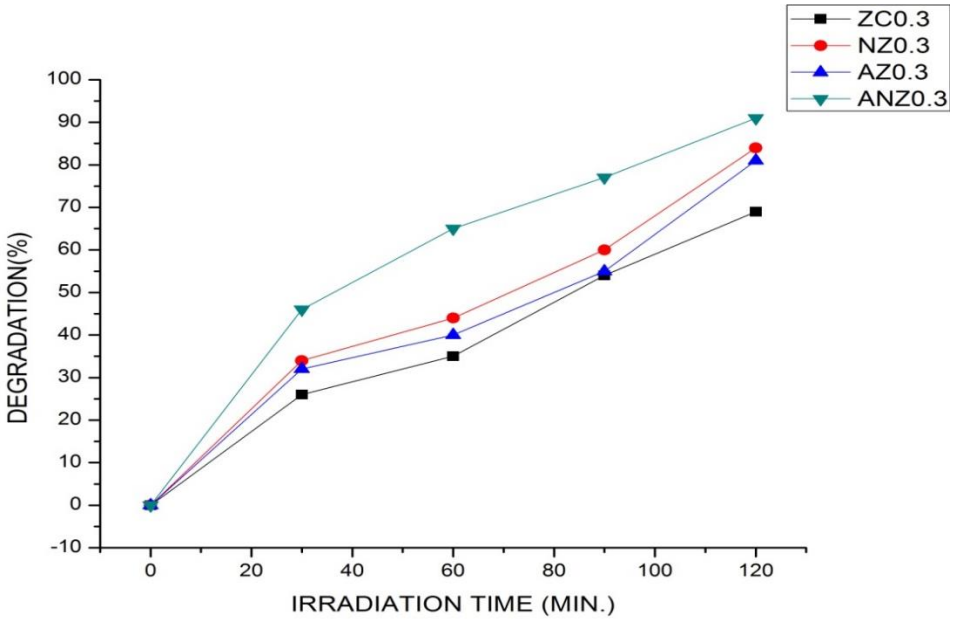


Fig. 4: Plots of Percentage Degradation of Gentian Violet as Function Of time Under Solar Irradiation

Table 3: Comparison Table of Photo catalyst Dosage from 0.1-0.4 at 120min under No Irradiation.

Photocatalyst Dosage	ZC (%)	NZ (%)	AZ (%)	ANZ (%)
0.1	5.1	6.3	9.2	12.0
0.2	6.3	7.1	9.3	12.1
0.3	7.1	7.2	10.5	13.2
0.4	6.5	6.2	9.4	12.1

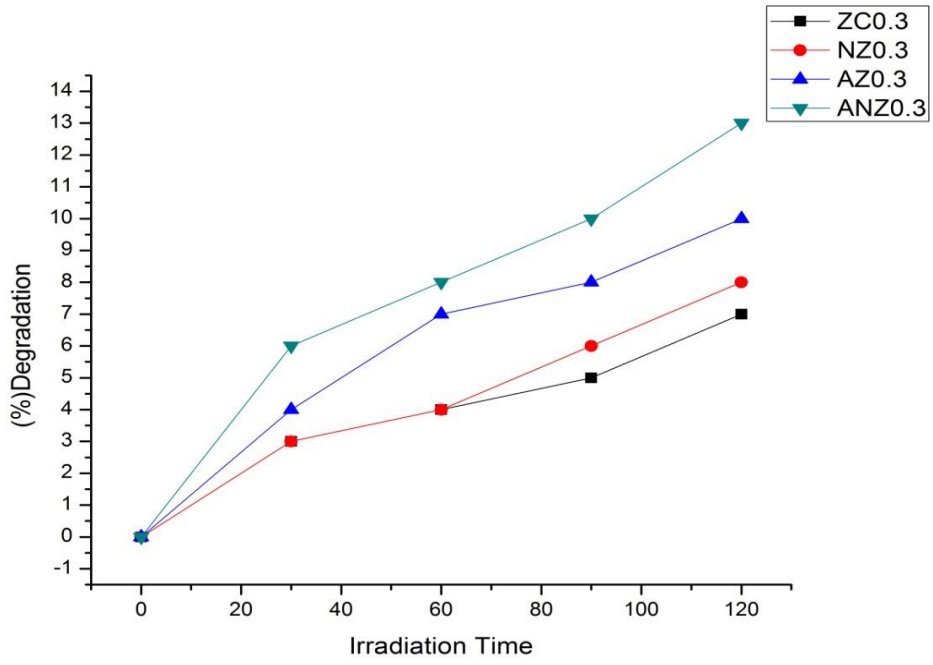


Fig. 5: Percentage Degradation of Gentian Violet as Function Of time Under No Irradiation.

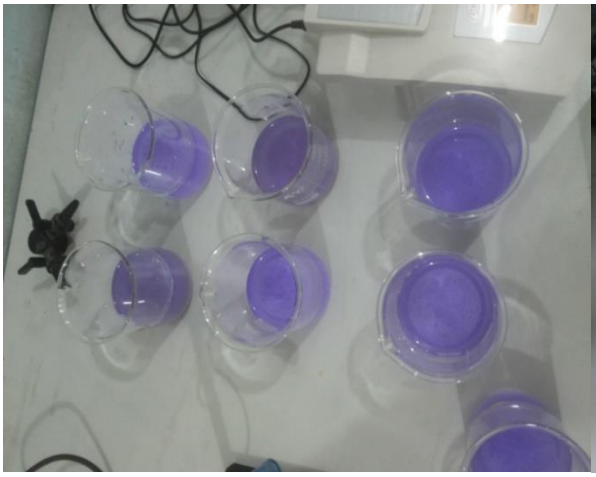


Plate 7: Gentian violet before irradiation

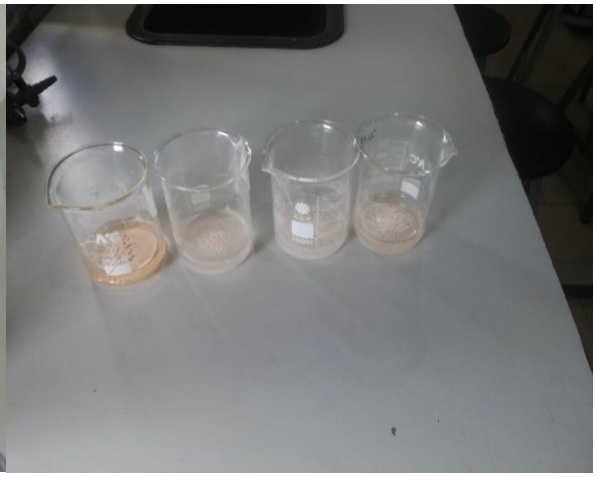


Plate 8: Gentian violet after irradiation

CONCLUSION

From the studies, it can be concluded that ZnO-assisted photocatalytic dye degradation proved to be significantly improved process over catalytic Reactions carried out in the dark, UV and Solar irradiation. On the basis of the results obtained from this preliminary study, the experimental methodology for subsequent studies has been established. The preparation of nanoparticles for Photocatalytic dye degradation was carried out using the "*one step liquid impregnatrion method.* For determining the crystallite size of the as-synthesized photocatalysts, X-ray diffraction (XRD) was used while SEM was used for determining average particle size of as-synthesized photocatalyst.

Result, shows that ANZ exhibited the highest degradation efficient than ZC, AZ and NZ both under UV and solar irradiation, while under solar irradiation NZ exhibited the highest degradation efficient than ZC and AZ. This implies that doping silver and nitrogen into zinc oxide modifies the electronic properties of zinc oxide, narrows its band-gap energy, extending its optical absorption to the visible light region. It enables N-doped ZnO to harvest more photons of solar radiations; thus, improving the photocatalytic activity of the semiconductor. Silver doped zinc oxide showed an enhanced photocatalytic activity for the degradation of Gentian Violet by facilitating electron-hole pair separation. Ag-N co-doping in zinc oxide had synergetic effect in enhancing its photo-catalytic activity. The optimum photocatalyst loading was determined at 3.0g.

REFERENCES

Aal, A.A.; Mahmud, S.A.; Aboul-Gheit, A.K. Mater. Sci. Eng. 2009, 29, 831.

Boczkaj, G., Fernandes, A. (2017). Wastewater treatment by means of Advanced Oxidation Processes at basic pH conditions: A review. *Chemical Engineering Journal*. 320.10.1016/j.cej.2017.03.084.

Chen, C.C., Lu, C.S., Chung, Y.C., Jan, J.L (2007). UV light induced Photodegradation of malachite green on TiO2 nanoparticles. *Journal of Hazardous Materials*, vol. 141, no. 3, pp. 520–528.

García-Montaño, J., Domènech, X., García-Hortal, J.A., Torrades,F., Peral, J.(2008). The testing of several biological and chemical coupled treatments for Cibacron Red FN-R azo dye removal. *Journal of Hazardous Materials*, vol. 154, no. 1–3, pp. 484–490.

El-Kemary, M., El-Shamy, H., El-Mehasseb, I. (2010). Photocatalytic degradation of ciprofloxacin drug in water using ZnO nanoparticles. Journal of Luminescence - J LUMINESC. 130. 2327-2331. 10.1016/j.jlumin.2010.07.013.

Jing, J., Li, J., Feng, J., Li, W., Yu, W. W (2013). Photodegradation of quinoline in water over magnetically separable Fe_3O_4/TiO_2 composite photocatalysts. *Chemical Engineering Journal*, vol. 219, pp. 355 –360.

Kang, S.Z.; Wu, T.; Li, X.; Mu, J. Colloids and Surfaces A: Physicochem. Eng. Aspects Doi: 10.1016/j.colsurfa.2010.08.029.

Kapinus, E. I.; Viktorova, T. I. (2010). *Theoretical and Experimental Chemistry*, *46* (3), 163-167.

Li D., Haneda, H. (2003). Enhancement of photocatalytic activity of sprayed nitrogen containing zinc oxide powders by coupling with metal oxides during the acetaldehyde decomposition. *Chemosphere* 54:1099–1110

Ren, C.; Yang, B.; Wu, V.X.; Fu, J.Z.I.; Guo, Y.T.; Zhao, Y.; Zhu, C. J. Hazard. Mater. 2010, 182, 123.

Sathishkumar, P., Pugazhenthiran, N., Mangalaraja, R. V., Asiri, A.M, Anandan, S (2013). ZnO supported $CoFe_2O_4$ nanophotocatalysts for the mineralization of Direct Blue 71 in aqueous environments. *Journal of Hazardous Materials*, vol. 252-253, pp. 171–179.

Senthilvelan, S., Chandraboss, V.L., Karthikeyan, B., Natanapatham, L., Murugavelu, M (2013) "TiO_2, ZnO and nanobimetallic silica catalyzed photodegradation of methyl green. *Materials Science in Semiconductor processing*, vol. 16, no. 1, pp. 185–192.

Sudarshan, S., Harikrishnan, S., Govindarajan, R., Karthik, A., Aanand, S. Rajasekar, A., Muthusamy, G. (2022). Impact of textile dyes on human health and bioremediation of textile industry effluent using microorganisms: current status and future prospects. *Journal of applied microbiology*. 134. 10.1093/jambio/lxac064.

Vinita, M., Dorathi, R.P.J., Palanivelu, K. (2010). Degradation of 2, 4, 6 trichlorophenol by photo Fenton's like method using nano heterogeneous catalytic ferric ion. *Solar Energy*, vol. 84, no. 9, pp. 1613–1618.

Vinu, R., Akki, S.U., Madras, G. (2010). Investigation of dye functional group on the photocatalytic degradation of dyes by nano-TiO_2. *Journal of Hazardous Materials*, vol. 176, no. 1–3, pp. 765–773.

Xia X., Zhu F., Li J, Yang H., Wei L., Li Q., Jiang J., Zhang G., Zhao Q. (2020) A Review Study on Sulfate-Radical-Based Advanced Oxidation Processes for Domestic/Industrial Wastewater Treatment: Degradation, Efficiency, and Mechanism. *Front Chem*.8:592056. doi: 10.3389/fchem.2020.592056. PMID: 33330379; PMCID: PMC7729018.

Zelmanov G., and Semiat, R (2008) Phenol oxidation kinetics in water solution using iron (3)-oxide-based nano-catalysts. *Water Research*, vol. 42, no. 14, pp. 3848–3856.

Zhang, Y.; Mu, J. J. Colloids and Interf. Sci 2007, 309, 478.

Zheng, M.; Wu, J. Appl. Surf. Sci. 2009, 255, 5656.

Zhou, W., Cao, M., Su, S (2013). A newly-designed polyoxometalate-based plasmonic visible-light catalyst for the photodegradation of methyl blue. *Journal of Molecular Catalysis and Chemical*, vol. 371, pp. 70–76.