様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

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研究課題名（和文）Building a Theory of Regular Structures for Non-Autonomous and Quasi-Linear Rough Evolution Equations, and Applying the Theory to Forest Kinematic Ecosystems

研究課題名（英文）Building a Theory of Regular Structures for Non-Autonomous and Quasi-Linear Rough Evolution Equations, and Applying the Theory to Forest Kinematic Ecosystems

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研究成果の概要（和文）：1) We have constructed strict solutions to a a class of semilinear evolution equation. 2) We have constructed SDE models for predator-avoidance swarms.
3) We have constructed a SDE model and its global solutions for a forest transition of forest land, agricultural land, and abandonment land sizes.

研究成果の学術的意義や社会的意義
New concept, named strict solutions, to a a class of semilinear evolution equations has been introduced. In addition, the mechanism of swarming behaviors and forest transition is also verified using SDEs approach.

研究成果の概要（英文）：1) We have constructed new concept, named strict solutions, to a a class of semilinear evolution equations in the paper:Ta, T.V., Strict solutions to stochastic semilinear evolution equations in M-type 2 Banach spaces. Communications on Pure & Applied Analysis, 20 (2021), 1867-1891. 2) We have investigated swarming behaviors: a) observed animal swarms avoiding predator to have a rule; b) constructed a mathematical model of
SDEs for predator-avoidance swarms by using the rule; c) performed simulations in some cases.+) Hartono, A.D., Nguyen, L.T.H., Ta, T.V.*: A stochastic differential equation model for predator-avoidance fish schooling. 39 pages, (https://doi.org/10.48550/arXiv.2210.03989). +) Hartono, A.D., Nguyen, L.T.H., Ta, T.V.*: A geometrical structure for predator-avoidance fish school. Proceedings of the Forum "Math-for-Industry" 2022.
3) We have constructed a SDE model and its global solutions for a forest transition of forest land, agricultural land, and abandonment land sizes.

研究分野：PDEs, SDEs, Applied mathematics

キーワード：PDEs　SDEs　Evolution equation　swarming behavior　forest transition　evolution equations　strict solutions

様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９（共通）

１．研究開始当初の背景

There are several non-equilibrium phenomena that have been observed, including rough heat equations, FKE, chemotaxis, adsorbate-induced phase transition, and Lotka-Volterra competition systems. These phenomena cannot be accurately described by autonomous evolution equations, as they are non-autonomous in nature. While regularity of solutions to autonomous evolution equations has been well-studied, there is a lack of research on the regularity of solutions to non-autonomous evolution equations. This gap in knowledge has resulted in many unknown mechanisms behind these non-equilibrium phenomena. Without a deeper understanding of the mathematical properties of these systems, it is difficult to accurately predict or explain observed behaviors. Therefore, there is a pressing need for further research on the regularity of solutions to non-autonomous and quasi-linear evolution equations, in order to better understand the underlying mechanisms of these important physical and biological processes.

２．研究の目的

Our goal is to develop a mathematical theory that will help us better understand non-autonomous evolution equations, and establish a framework for regularity results that can be applied to a variety of phenomena. By exploring the properties of solutions to non-autonomous evolution equations, we hope to uncover the underlying mechanisms that govern these systems and shed light on their behavior.

In addition to our work on regular structures for non-autonomous evolution equations, we also plan to investigate the effects of noise on the dynamics of forest kinematic ecosystems and swarm behaviors. Noise is ubiquitous in natural systems, and can have a profound impact on their behavior. By studying the interplay between noise and the dynamics of these systems, we hope to gain new insights into the mechanisms that drive these systems and improve our ability to predict their behavior under different conditions. Ultimately, our goal is to contribute to a deeper understanding of complex natural systems and to develop new tools and techniques for analyzing and predicting their behavior.

３．研究の方法

We employed an analytical semigroups approach and stochastic integrals in Banach spaces of M-type 2 to investigate the regularity of solutions to non-autonomous evolution equations.

Furthermore, we studied several models described by stochastic differential equations, including the forest transition model and swarm behaviors. By simulating these models using MATLAB/Python, we were able to gain insights into the effects of noise on the dynamics of these systems. Our results suggest that noise can have a significant impact on the behavior of these systems.

Overall, our study provides a significant contribution to the field of mathematical modeling, as it offers a new theoretical framework for the regularity of solutions to non-autonomous evolution equations. By using a combination of analytical and computational tools, we were able to gain a deeper understanding of the dynamics of complex systems and the effects of noise on their behavior.

４．　研究成果

a) We have constructed strict solutions to a class of semilinear evolution equations.
b) We have also constructed systems of stochastic differential equations to describe swarm behaviors and discovered interesting patterns.
c) We have constructed an SDE model and its global solutions for a forest

transition of forest land, agricultural land, and abandonment land sizes.

Our results have been published in international scientific journals.

1. Ta, T.V.: Strict solutions to stochastic semilinear evolution equations in M-type 2 Banach spaces. *Communications on Pure & Applied Analysis*, 20 (2021), 1867-1891.
2. Nguyen, L.T.H., Ta, T.V. and Yagi, A.: A brief review of some swarming models using stochastic sifferential equations. *Proceedings of the Forum "Math-for-Industry" 2018*, 35 (2022), 163-179.
3. Hartono, A.D., Nguyen, L.T.H., Ta, T.V.: A stochastic differential equation model for predator-avoidance fish schooling. 39 pages, preprint submitted to a journal. (https://doi.org/10.48550/arXiv.2210.03989).
4. Hartono, A.D., Nguyen, L.T.H., Ta, T.V.: A geometrical structure for predator-avoidance fish school. To appear in *Proceedings of the Forum "Math-for-Industry" 2022.*
5. Gao, Y., Banerjee, M, Ta, T.V.: A sustainability condition for a stochastic Holling-Tanner predator-prey model with infectious disease. (submitted).
6. Kumabe, S., Ta, T.V: Dynamics of a stochastic forest transition model. In preparation.

５．主な発表論文等

〔雑誌論文〕　計2件（うち査読付論文　2件／うち国際共著　2件／うちオープンアクセス　1件）

１．著者名 Nguyen Linh Thi Hoai、Ta Ton Viet、Yagi Atsushi	４．巻 35
２．論文標題 A Brief Review of Some Swarming Models Using Stochastic Differential Equations	５．発行年 2022年
３．雑誌名 Proceedings of the Forum "Math-for-Industry" 2018	６．最初と最後の頁 163～179
掲載論文のDOI（デジタルオブジェクト識別子） 10.1007/978-981-16-5576-0_9	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

１．著者名 Ton Viet Ta	４．巻 2021050
２．論文標題 STRICT SOLUTIONS TO STOCHASTIC SEMILINEAR EVOLUTION EQUATIONS IN M-TYPE 2 BANACH SPACES	５．発行年 2021年
３．雑誌名 Communications on Pure and Applied Analysis	６．最初と最後の頁 1-25
掲載論文のDOI（デジタルオブジェクト識別子） 10.3934/cpaa.2021050	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

〔学会発表〕　計1件（うち招待講演　1件／うち国際学会　1件）

１．発表者名 Ta, T.V.
２．発表標題 Stochastic Dierential Equation Models for Swarm Behavior
３．学会等名 The 7th International Conference on Random Dynamical Systems（招待講演）（国際学会）
４．発表年 2022年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関