# beanstalk.pdf

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Page 1

Abstract

Financial applications built on decentralized, permissionless computer networks often require a "stablecoin": a network-native asset with sufficiently low volatility in value relative to an arbitrary value peg. Beanstalk is an Ethereum3 -native, fiat stablecoin protocol that issues an ERC-20 Standard4 token that fulfills these requirements.

Page 5

1 Introduction

Decentralized computer networks that run on open source, permissionless protocols present the next economic and technological frontiers: trustless goods and services. These networks are built on open source software and allow anyone to verify the security, authenticity and policies for themselves.

The use of trustless computer networks for real economic activity is limited by the lack of a trustless network-native asset with competitive carrying costs, low volatility endogenous value and deep liquidity.

A stablecoin protocol attempts to generate a fungible network-native asset and keep its price volatility sufficiently low relative to an arbitrary value peg. Its utility is a function of trustlessness, carrying costs, stability and liquidity.

1.1 Convertible Stablecoins

Non-network-native exogenous value convertible stablecoin protocols issue stablecoins that claim to be collateralized by non-network-native assets. However, users sacrifice permissionlessness and carry entirely because third parties custody the non-network-native assets and can retain yield earned on collateral.

Page 6

Network-native exogenous value convertible stablecoin protocols use excess network-native collateral to remove most points of centralization. Liquity12 is an ideal simple iteration of a network-native exogenous value convertible stablecoin protocol.

Exogenous value convertible stablecoin implementations have several shortcomings, but demand for their USD implementations continues to increase rapidly. However, borrowing rates on exogenous value convertible USD stablecoins have historically been higher than borrowing rates on USD.

1.2 Non-convertible Stablecoins

Stablecoins without convertibility to collateral have the potential to create endogenous value that facilitates trustlessness, competitive carrying costs and deep liquidity.

Fiat currency is derived from the credit of its issuer and its utility. Decentralized credit can be used to issue a permissionless fiat stablecoin with competitive carrying costs, low volatility and deep liquidity.

Page 7

1.3 Beanstalk

Beanstalk uses a dynamic peg maintenance mechanism to regularly cross the price of 1 Bean over its value peg, creating user confidence to regularly buy and sell Beans at their value peg.

Beanstalk consists of five interconnected components: a decentralized timekeeping and execution facility, a decentralized governance facility, a decentralized credit facility, a decentralized exchange, and an interface to interact with other Ethereum-native protocols via Beanstalk.

Beanstalk is designed from economic first principles to create a useful trustless fiat currency. Its carrying costs decrease but remain competitive.

2 Previous Work

Beanstalk is the culmination of previous development, evolution and experimentation within the DeFi ecosystem and is a decentralized stablecoin that leverages the existence of non-network-native exogenous value convertible stablecoins that trade on AMMs.

Page 8

Beanstalk is a decentralized protocol that creates utility for end users without requiring, but never limiting, participation in protocol maintenance. Its five primary components are the Sun, Silo, Field, Market and Depot, which are all managed by a stalwart system of governance.

The Silo is a passive yield opportunity for owners of and other assets on the Deposit Whitelist. Stalkholders govern Beanstalk upgrades and are rewarded with Beans when the supply increases.

The Beanstalk governance and peg maintenance mechanisms require a protocol-native timekeeping mechanism and regular code execution on the Ethereum blockchain. The Sun creates a cost-efficient protocol-native timekeeping mechanism and incentivizes cost-efficient code execution on Ethereum at regular intervals.

Page 9

The cost to execute the sunrise function on the Ethereum network changes depending on the traffic on the network and the state of Beanstalk.

5 Silo

The Silo uses the Stalk System to coordinate protocol upgrades and improve security, stability and liquidity. Stalkholders earn passive yield and contribute actively to peg maintenance.

5.1 The Stalk System

Anyone can become a Stalkholder by Depositing assets on the Deposit Whitelist into the Silo to earn Stalk and Seeds. Stalk are not liquid.

5.2 Deposit Whitelist

Page 10

To add a to the Beanstalk, you need the token address, a function to calculate the flash-loan-resistant Bean-denominated-value for a given number of deposited, the number of Stalk and Seeds per BDV, and the number of Z+.

Beanstalk rewards Stalk and Seeds to Depositors immediately upon Depositing based on its BDV when Deposited, k , and c . These rewards must be forfeited upon Withdrawal from the Silo.

Conversions of Deposited tokens to Deposited ′ are permissioned by a Convert Whitelist. Conversions can be added or removed from the Convert Whitelist via Beanstalk governance.

Page 11

5.4 Calculating Stalk and Seeds

A Stalkholder's total Stalk is the sum of the Stalk for each of their Deposits and Earned. Earned automatically earn Stalk the next time the Stalkholder calls the plant function.

When a Stalkholder Deposits , Beanstalk updates the total number of Deposits during Season i and its total BDV when Deposited. Beanstalk stores a map of each Stalkholder's Deposits that are still in the Silo.

A Stalkholder's total Stalk during t is equal to the sum of their Grown Stalk that can be Mown during t to start earning Bean seigniorage and their total Grown Stalk that can be Mown during t. A Stalkholder's total Seeds during t are determined by its BDV when Deposited and c . The Plantable Seeds associated with a Stalkholder's are determined by c .

Page 12

5.5 Governance

A robust decentralized governance mechanism must balance the principles of decentralization with resistance to attempted protocol changes, and the ability to quickly adapt to changing information.

5.5.1 Participation

Any Stalkholder can submit a BIP via the Beanstalk Community Multisig 26 (BCM ). A Stalkholder's vote is counted in proportion to their Stalk when the BIP is submitted to Snapshot.

The award for submitting a BIP is determined by the submitter, and if the award is excessively high, someone else can re-submit an identical BIP.

Page 13

5.5.4 Beanstalk Improvement Proposals

Beanstalk is a diamond with multiple facets that implements EIP-2535.28. It supports multiple simultaneous BIPs with independent Voting Periods.

5.5.5 Beanstalk Community Multisig

The BCM address has the exclusive and unilateral ability to Pause and Unpause Beanstalk, and submit and commit BIPs. It is a 5-of-9 Safe29 multisig wallet with anonymous signers.

The Beanstalk peg maintenance mechanism requires the ability to borrow Beans. The Field is the Beanstalk credit facility, and the Temperature is the interest rate on Bean loans.

Page 14

6.2 Pods

Pods are the primary debt asset of Beanstalk. They Yield from Sown and never expire, and Ripen when the average price of 1 is above its value peg over a Season.

Page 15

7.1 Fertilizer

Fertilizer is a limited debt issuance that automatically Fertilizes Sprouts and never expires. It can be bought from Beanstalk in exchange for 1 USDC each.

When the price of 1 is above its value peg over a Season, Active Fertilizer Fertilizes Sprouts such that they become Rinsable (redeemable) for 1 at anytime. Fertilizer owners can Rinse their Rinsable Sprouts anytime by calling the rinse function.

Page 16

7.3 Recapitalization

Beanstalk uses proceeds from the sale of Fertilizer to recapitalize non-Beanstalk-native value stolen from Stalkholders in the April 17th, 2022 governance exploit.

Non-Beanstalk-native and Beanstalk-native value stolen from Stalkholders are recapitalized simultaneously via Unripe assets, which entitle holders to an associated number of Ripe assets. Holders of Unripe assets can Chop them to receive a portion of the associated Ripe asset.

7.3.1 Available Fertilizer

The number of Available Fertilizer is equal to the difference between the total Fertilizer and the total Fertilizer sold. It is a function of the current total Unripe and the total Unripe at the time of Replant.

Page 17

Upon Replant, Stalkholders receive a portion of their Stalk, Seeds and Plantable Seeds based on the percentage of Fertilizer sold prior to the Exploit. As the percentage of Fertilizer sold increases, additional Stalk and Seeds are Revitalized.

A Stalkholder's Seeds upon Replant are equal to their Seeds at the end of the block prior to the Exploit.

The number of Revitalized Stalk and Revitalized Seeds that can be Enrooted by a Stalkholder during t is a function of the change in X between the Season they last called the enroot function and t.

7.3.3 Unripe Assets

Holders of Beans received Unripe (z) at a 1:1 ratio, holders of , but not Deposited, received Unripe (z) at a ratio of 1 z per BDV of , but not Deposited, per Deposit.

Page 18

The number of Ripe assets increases as more Fertilizer is sold. The change in Ripe is a function of the total Unripe, the Ripe prior to the purchase, and the Fertilizer sold prior to the purchase.

We define M as the number of Sprouts not yet Fertilized by Active Fertilizer received for Chopping a given z, and P as the number of Beans received for Chopping a given z.

Page 19

8 Peg Maintenance

Beanstalk must encourage widespread participation in peg maintenance through protocol-native financial incentives, and regularly crosses the price of 1 over its value peg.

At the beginning of every Season, Beanstalk adjusts the Bean supply, Soil supply, and Temperature to move closer to ideal equilibrium.

Page 20

8.1 Ideal Equilibrium

The Beanstalk is in ideal equilibrium when the Bean price and the Beanstalk debt level are both stable at their optimal levels.

Beanstalk adjusts the supply and demand for Beans and Soil to return to ideal equilibrium, by adjusting the Bean supply, Soil supply and Temperature. It closely monitors the states of both the Bean and Soil markets.

8.2 Decentralized Price Oracle

Beanstalk uses network-native decentralized AMMs, non-network-native exogenous value and network-native exogenous value convertible stablecoins to create an immutable, manipulation resistant and decentralized source for the price of a non-Ethereum-native value peg.

The Ethereum-native permissionless AMM protocols allow anyone to create new AMMs between at least two ERC-20 Standard tokens. AMMs allow continuous trading in either direction by maintaining a liquidity pool of the tokens.

A decentralized system, Beanstalk, can issue a Bean with a value peg for 1 equal to any non-network-native asset with at least one existing ERC-20 Standard convertible stablecoin that offers low-friction convertibility to V and trades on an AMM against a liquid, decentralized network-native asset with endogenous value.

Page 21

Beanstalk never calculates the price of 1 but instead calculates a sum of liquidity and time weighted average shortages or excess of Beans across all liquidity pools.

The liquidity and time weighted average price of 1 compared to V over the previous Season can be inferred using a price ratio.

8.3 Debt Level

We define the total Bean supply as the sum of all Beans minted over all seasons, total awards for all committed Beans minted via BIP, total Burnt over all seasons, and total Sown over all seasons.

Beanstalk requires three levels of debt: low, optimal, and high. When low, optimal, and high are equal, debt is considered reasonable.

Page 22

8.4 Position

The current state of Beanstalk is determined in part by its position with respect to ideal equilibrium.

8.5 Direction

When the Pod Rate at the end of the previous Season is greater than the Ideal Rate, the Beanstalk will move toward ideal equilibrium; when it is less than ideal, it will move away from ideal equilibrium.

8.6 Acceleration

The acceleration of Beanstalk is considered decelerating, steady or accelerating, based on Pt1 and changing demand for Soil. Demand for Soil is considered decreasing, steady or increasing.

Page 23

When demand for Soil is increasing, Beanstalk is either accelerating or decelerating, depending on the value of Pt1.

8.7 Demand for Soil

Beanstalk must accurately measure changing demand for Soil in order to properly classify its acceleration.

Beanstalk requires two levels to be set: tS lower and tS upper. When tS lower tS upper , demand for Soil is considered steady.

Page 24

When Beans are Sown in all Soil in a Season, but not in all but at most one Soil in consecutive Seasons, the difference in time it took for the Beans to be Sown in all but at most one Soil over the previous two Seasons can provide a more accurate measurement.

∆Etufirst = Etufirst − Et

If Beans were Sown in all but one soil in the first 5 minutes of the previous Season, demand for soil is considered increasing.

∆Etu = ∆Etu−first2 − ∆Etu−first1

When the above condition is met, changing demand for Soil is measured by etu . etuupper is the level above which demand for Soil is considered increasing.

8.8 Current State

We define six potential states for Beanstalk with respect to ideal equilibrium, including accelerating away from ideal equilibrium, steady away from ideal equilibrium, and accelerating toward ideal equilibrium.

Page 25

8.9 Optimal State

An optimal state of Beanstalk is either accelerating toward ideal equilibrium or either steady or decelerating toward ideal equilibrium, depending on its current debt level.

8.10 Bean Supply

At the beginning of each Season, Beanstalk increases the Bean supply based on the sunrise function.

If there are less Unfertilized Sprouts than Fertilized Sprouts, then less Unfertilized Sprouts than Fertilized Sprouts, then more Fertilized Sprouts than Fertilized Sprouts become Rinsable.

Page 26

The distribution of remaining Beans depends on the number of Unharvestable Pods. If there are less Unharvestable Pods than there are Ripening Pods, then less Ripening Pods become Harvestable and more Ripening Pods become Harvestable.

8.11 Soil Supply

Beanstalk sets the Soil supply at the beginning of each Season based on the number of Pods that Ripen and become Harvestable, the Temperature during t, and RtD1.

8.12 Temperature

Beanstalk adjusts the Temperature at the beginning of each Season in an attempt to maintain an optimal state, or to move from its current state into an optimal state.

Page 27

When the debt level is excessively high, the temperature is raised 3%, lowered 1%, kept constant, or lowered 3% depending on the current state. When the debt level is reasonably high, the temperature is raised 3%, lowered 1%, kept constant, lowered 3%, and raised 1% depending on the current state. When the debt level is reasonably low, the temperature is lowered 3%, 1%, kept constant, raised 1%, and 3%, depending on the current state. When the debt level is excessively low, the temperature is raised 3%, 1%, kept constant, raised 1%, and raised 3%, depending on the current state.

Page 28

8.13 Flood

When the Farm becomes Oversaturated, Beanstalk returns the price of 1 in each liquidity pool on the Oracle Whitelist to its value peg by minting additional Beans and selling them directly in the pools.

The optimal number of Beans to mint and sell to return the price of 1 to its value peg is calculated from the sum of differences.

Page 29

9 Market

Current DEXs are unable to attract liquidity without offering protocol-native emissions derived primarily from AMM trading fees. Beanstalk's Market provides liquidity without fee-based emissions.

10 Depot

The Depot allows complex interactions with other Ethereum-native protocols in a single transaction. Pipelines can be added via Beanstalk governance.

11.1 Ownership Concentration

A design that lowers the Gini coefficient of Beans and Stalk over time is essential to censorship resistance.

11.2 Strong Credit

Beanstalk is credit based and only fails if it can no longer attract creditors.

Page 30

11.4 Low Friction

Beanstalk maximizes utility for users and appeal to creditors by minimizing the cost of using Beans and barriers to the Farm. The Depot realizes the full benefits of composability on Ethereum.

11.5 Equilibrium

The supply of and demand for Beans are affected by the temperature and the Bean price. By changing the temperature, Beanstalk affects decreases in the Bean supply and changes in demand for Beans.

11.6 Incentives

The Stalk System incentivizes Stalkholders and Sowers to leave assets in the Silo continuously, to add value to liquidity pools with Beans, and to return the price of 1 to its value peg.

The Stalk System and Withdrawal Freeze reduce the incentive to Withdraw assets from the Silo.

Page 31

There are numerous risks associated with Beanstalk, including that others could take advantage of any bugs, flaws or deficiencies in Beanstalk and launch identical or very similar stablecoin implementations.

A decentralized implementation of Beanstalk has three external dependencies: a trustless computer network, a DEX protocol, and a non-network-native stablecoin protocol.

The Ethereum blockchain, ERC-20 Standard, Curve, USDC, USDT and DAI are the most developed decentralized smart contract platform, have an active community, and have long track records of security.

The Beanstalk price oracle contains exposure to risk related to the underlying collateral of x (USDC, USDT, DAI). If the price of x falls below V , it would cause some short run excess inflation of the Bean supply.

13 Future Work

Page 32

Permissionless governance can be reimplemented, Stalk can become liquid, the Silo can support additional token standards, the Withdrawal Freeze can be removed, the decentralized price oracle can be significantly improved, the Market can be further developed, and the Depot can support additional Pipelines.

Page 33

14.1 Current Parameters

The current parameters of Beanstalk are: - , K min, w1, RS min, RS max, RD lower, tS lower, tS upper, rtS upper, and etulower, etuupper.

Page 34

14.2.2 Φ

The BDV of a Beanstalk token is calculated by calling the Curve40 get D function on the token address, the number of Beans in the pool, the number of 3CRV in the pool at the end of the last block, and the virtual price. Beanstalk calculates a flash-loan-resistant total number of 1 and a flash-loan-resistant USD price of 1 from the BEAN:3CRV Curve pool. Beanstalk calculates the BDV of 3CRV for a given 1 , f 3CRV (z 3CRV ), 3CRV1 and 1 as: f 3CRV (z 3CRV ) = z 3CRV , P 3CRV $()1

Page 35

The z token address is 0x1BEA0050E63e05FBb5D8BA2f10cf5800B6224449. The BDV of z is calculated using f (z ), L and Z .

14.2.4 zΦ

z tokens are issued with an address 0x1BEA3CcD22F4EBd3d37d731BA31Eeca95713716D. z deposits receive 1 Stalk per BDV upon Deposit.

Page 36

When a BIP passes, it must be manually committed to the Ethereum blockchain. The award for successful commitment compounds every six seconds for 1,800 seconds.

Page 37

Deposited can be converted to a Deposit at anytime. The number of received for Converting Deposited is equivalent to the number of Converted.

The BEAN:3CRV Curve pool price invariant is calculated by calling the Curve get D function on , 3CRV and P 3CRV and calculating a total number of , such that j 1018 | j Z+ , from , P and . The number of deposits received for converting deposited beans within the Silo is calculated by calling the Curve add liquidity function on and .

Page 38

The number of Beans received for Converting Deposited within the Silo for a given minimum Beans received is the result of calling the Curve remove liquidity one coin function on .

To convert z tokens to r tokens, you must have the price of 1 in the BEAN:3CRV liquidity pool less than or equal to $1. The Convert Function is calculated using the Curve Add Liquidity Function.

To convert z tokens to cash, you must have a price of $1 or greater in the pool, and at least z min.

Page 39

14.5 Barn

The following ERC-20 Standard tokens were Whitelisted for Deposit in the Silo at the end of the block prior to the Exploit. All deposits receive 4 Seeds per BDV upon Deposit.

14.5.1 Old

The old token address is 0xDC59ac4FeFa32293A95889Dc396682858d52e5Db, the BDV function is 1, the stalk per BDV is 1, the seed per BDV is 2, and the total supply is 108155457.359439 old.

14.5.2 Old BEAN:ETH Uniswap V2 LP Tokens (ב)

The BDV of was calculated using the last traded price in the BEAN:ETH Uniswap v2 pool, unless there was an interaction with the pool in the current block. If there was an interaction with the pool and the sunrise function was also called in the current block, deposits are not accepted.

The total supply of was 0.540894218294675521 and the BDV per token was 119,894,802.186829.

Page 40

14.5.3 Old BEAN:3CRV Curve LP Tokens (ד)

The token address is 0x3a70DfA7d2262988064A2D051dd47521E43c9BdD, and the BDV function was calculated using the number of Beans, the number of 3CRV in the old BEAN:3CRV Curve pool at the end of the last block, and the virtual price. Beanstalk calculated a flash-loan-resistant total number of 1 and a USD price of 1 using the BEAN:3CRV Curve pool. Beanstalk calculated the value of a bean (z 3CRV) for each block (i.e., k = 1), and then divided the value by the number of blocks in the block (i.e., k = 1).

14.5.4 Old BEAN:LUSD Curve LP Tokens (ג)

The BDV of was calculated using the number of LUSD and 3CRV in the LUSD:3CRV Curve pool at the end of the last block, the A parameter of the pool, the virtual price and the flash-loan-resistant price invariant for the LUSD:3CRV Curve pool.

Page 42

The liquidity pool for the BEAN:3CRV Curve is calculated as the difference between the optimal liquidity and time weighted average number of Beans and the liquidity and time weighted average number of Beans in the previous Season.

Page 44

14.8.1.1 Pod Orders

Anyone with Beans not in the Silo can Order Pods by entering the maximum number of Pods to be purchased, the maximum place in the Pod Line to purchase from, and the price per Pod.

14.8.1.2 Pod Listings

A Plot is a collection of Beans that were Sown from a single call of the sow function. Anyone with a Plot can List a whole or partial Plot to be sold for Beans.

Page 45

A Pod Listing can be Cancelled at any time until it is entirely Filled.

14.8.1.3 Clearance

A Pod Order can be partially filled by a Pod seller, and a Pod Listing can be partially filled by a Pod buyer.

14.8.1.4 Future Work

Multiple Plots can be listed in the same Pod Listing, and overlapping Pod Orders and Pod Listings can be cleared automatically.

Page 47

14.10 Fundraisers

Fundraisers are created via Beanstalk Improvement Proposals and mint new Beans. They allow Beanstalk to issue Pods in exchange for assets pegged to V other than Beans, independent of the Soil minting schedule, in order to raise funds to facilitate payments in other currencies.

14.10.1 Trail of Bits Audit45

Page 48

This paper uses lower case Latin letters for unique values, upper case Latin letters for totals or rates, Mathfrak style Latin letters for the Barn, and Hebrew letters for assets.

The Beanstalk recapitalization facility, the Beanstalk Community Multisig, the Barn, the total Bean supply, the total Beans minted via BIP, the total awards for all committed BIPs, the total award for successfully calling the sunrise function for t are all described.

Page 49

The Beanstalk contract stores information about assets such as Beans, Beanstalk Community Multisig, Beanstalk Improvement Proposal, Burnt, Old BEAN:ETH Uniswap V2 LP tokens, the last traded price, and the time weighted average number of Beans in the current block. DAO is a decentralized autonomous organization; DeFi is a decentralized finance; Deposit is an asset in the Silo; Depositors are wallets that have Deposited assets into the Silo; Depot is a portion of the Farm that facilitates interactions with other Ethereum-native protocols; and Bt1 is the number of Beans minted.

Page 50

The sum of the liquidity and time weighted average shortages or excesses of Beans across :y liquidity pools on the Oracle Whitelist over the previous Season. The number of Pods that Ripen and become Harvestable at the beginning of each Season is related to the number of Sprouts that are fertilized by active fertilizer and become Rinsable at the beginning of each Season. The change in Ripe is proportional to the change in Soil from the beginning to the end of each Season. The old BEAN:3CRV Curve LP tokens, the flash-loan-resistant total number of Beans, the number of 3CRV in the old BEAN:3CRV Curve pool at the end of the last block, the timestamps of the last interaction with , the timestamp Beanstalk last unpaused.

Page 51

The April 17th, 2022, governance exploit of Beanstalk is a function that determines the number of Beans received for Converting a given number of , the flash-loan-resistant Bean-denominated-value for a given number of deposited , and the liquidity and time weighted average price invariant for . The temperature during t is used to calculate the amount of Grown Stalk that can be Mowed by a Stalkholder to start earning Bean seigniorage for a given Deposit.

Page 52

The temperature, humidity, harvest, harvestable, harvested, redeemed, humidity, interest rate, stalk, total stalk, and harvest time are all variables. The BIP is calculated based on the percentage of Stalk ownership necessary to submit a BIP, the number of Stalk per BDV of deposited, the total BDV of Zi when Deposited, the total Beans minted over all Seasons, and the total Burnt over all Seasons.

Page 53

Beanstalk accepts sunrise function calls, pauses accepting sunrise function calls, plants seeds, and plots beans. Pods are the primary debt asset of Beanstalk. They are bought and sold on the Pod Market, and are redeemed for Soil, Revitalized Seeds, Revitalized Stalk, Rinsable Sprouts, Rinse, Stend, Stmin, Ststart, S, and R.

Page 54

A Beanstalk DAO uses a Seed, Soil, Sower, Sown, Sprouts, Sun, BEAN:3CRV LP tokens, A, MIN, 1 and t1 to calculate the optimal number of Beans in the Curve pool at the end of each Season. The optimal liquidity and time weighted average number of Beans in a portfolio over the previous Season is . The Season a Stalkholder last called the enroot function, the number of Revitalized Seeds and Stalks that can be enrooted, the interest rate on Bean loans, and the number of Sown.

Page 55

Unfertilized Sprouts, Unharvestable Pods, Unpaused Beanstalk, Unripe assets, Used Fertilizer, The value peg for 1, Available Fertilizer, Available Fertilizer purchased with Humidity H, Voting Period, Withdraw, Withdrawal Freeze, Withdrawn assets. A liquid, decentralized network-native asset with endogenous value is created from a percentage of Fertilizer sold, a current total Unripe , a total number of deposited Unripe , a minimum number of Unripe , a total number of Unripe , and a maximum number of Unripe .

Page 56

14.12 Whitepaper Version History

Whitepaper version 1.0.0 was corrected to reflect that the first Season began when the init function was called as part of the Beanstalk deployment. Versions 1.0.1 - 1.1.2 were corrected to reflect the correct base commit award. - Updated Section 8.4.8 to reflect the latest Weather changes, created an Appendix, and updated Section 12.1 to reflect an updated understanding of potential uses of Beanstalk.

Page 57

1.3.1 (December 3, 2021): Removed a sentence from Section 6.2, updated Section 6.3 to reflect the new Stalk equations, added a comma in Section 8.3, and italicized Stalk in the change history for Version 1.1.0. 1.4.0 (December 10, 2021): Added ht to the Glossary. 1.5.0 (December 18, 2021): Modified language in Section 3, switched all > to , and updated Section 6.2, 6.3, 9.6, and Figure 1 to reflect new Convert mechanism. - 1.6.0 (January 12, 2022) - Modified the last sentence of the Abstract for better flow, changed a semicolon to a colon in the fourth paragraph of Section 1, corrected a typo in the second paragraph of Section 3, updated Section 4, and modified Section 6.1, 6.2, 6.3, and 6.4 for clarity.

Page 58

Changed variable Ef to E in Section 6.4.3 and the Glossary, corrected typos in Section 6.4.4 and Section 6.4.5, modified the language of Section 7.2, updated Section 8.2 to reflect the new Bean supply policy, and updated Section 8.3 to reflect the new Soil supply policy. The update corrects a typo in the first paragraph of Section 8.4.1, modifies the language of the second paragraph of Section 8.4.3 for clarity, updates Section 8.4.5 to reflect the new Soil supply policy, and modifies Section 8.4.7 to reflect the new Season of Plenty timer. Modified section title, language of first paragraph, conventions in Section 12.2, added K min , Silo , and to the Glossary, and removed Bt , Stmax , and RSmax from the Glossary.

Page 59

Added a new Section 12.2 to the Appendix, changed Deposit in the Glossary, moved Optimal State to reflect correct alphabetical ordering, added Cancel, Farmers Market, Fill, Listing, Plot, Pod Line, Pod Listing, and Withdrawal to the Glossary, and added c, ct, g, k, Kt, l, , , z and Zi. The Whitepaper Version History links have been updated to reflect the new Weather changes, as amended by BIP-13.52. - 1.9.2 (April 1, 2022): Corrected a typo in the first paragraph of Section 6.2, updated Section 6.5.5 to reflect the correct rate and duration that aq compounds, added a new Section 12.2 to describe the Silo Whitelist, and corrected two typos in the Glossary.

Page 60

1.15.0 (April 7, 2022) - Moved to a new whitepaper versioning system, updated Section 8.4.5 to reflect the new method to measure demand for Soil, added a comma to the Glossary, and modified Section 12.2.2 and 12.2.3 for consistency. The whitepaper was overhauled in 2022 to reflect the state of Beanstalk after the Replant, and eight instances of improper punctuation were corrected. A new Section 14.4.1 was added, and the date of modification was corrected.